CANMET

CANMET REVIEW 1981-82

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CANMET

Canada

CANMET REVIEW 1981-82

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Canada Centre for Mineral and Energy Technology,
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FOREWORD

The Canada Centre for Mineral and Energy Technology (CANMET) has carried out research and development and the transfer of information and technology to meet the needs of government, industry and the public at large, since its inception in 1907. Therefore, 1982 is the 75th anniversary of the branch. It will be marked by the publication of a history of the organization entitled "A Canadian Research Heritage" by A. Ignatieff. Alex Ignatieff devoted 25 years of his professional career to the Mines Branch. This outstanding international scientist and science manager contributed much to shaping the history of CANMET, and its prestige is due to the calibre of such scientists in the history of the branch.

This review exemplifies the diversity of the ongoing research undertaken by CANMET, which includes the successful development of the CANMET hydrocracking process to a point where Petro-Canada has decided to build a demonstration plant, the bench-scale continuous-flow coal liquefaction unit that places CANMET in the forefront of coal-bitumen co-processing technology, and developments in combustion, carbonization and fluidized-bed research that have resulted in substantial advances in fuels technology.

In the metals field substantial progress has been made in several areas, such as the commercialization of the CANMET system for in situ casting of hard facings, the CANMET portable X-ray stress diffractometer, CANMET degradable sand binder systems, and CANMET fluidized-bed heat treatment technology.

Efforts were intensified to develop technology for processing complex sulphide minerals and the utilization of waste materials. Coal preparation, uranium processing and research in ceramics were also prominent areas of work.

Important advances were made on several fronts in mining technology including the development of methods for mining at greater depths, particularly the control of poor ground conditions; in the health and safety of miners, the control of the underground environment and combatting the dangers of explosive atmospheres in gaseous mines. Considerable emphasis was given to coal mining technology.

At the end of 1981 it was decided to establish a new organizational unit, the Coal Research Laboratories, comprising the Coal Mining Laboratory at Calgary, the newly formed Coal Health and Safety Laboratory in Sydney, and the Coal Preparation Laboratory in Edmonton. Also, an Office of Technology Transfer was created in order to emphasize and define the process of technology transfer of CANMET research results, as well as to review completed projects and to perform long-term strategic planning.

The branch continued to be well served by the outstanding quality and capability of its scientists, engineers, technical and support staff.

W.G. Jeffery,
Director-General

INTRODUCTION

The federal Department of Energy, Mines and Resources aims to ensure the effective use of Canada's energy and mineral resources by determining the country's natural resource potential, improving resource technology, evaluating economic and social factors, formulating and implementing policy, and transferring to governments, industry and the public new technology related to energy and mineral resources.

The 1981-82 review describes various contributions by the Canada Centre for Mineral and Energy Technology to the above objectives.

In energy research, emphasis was placed on: energy sources, conservation, petroleum supply technology - oil sands mining, bitumen and heavy oil recovery; coal technology; nuclear energy - processing, waste disposal; materials for heavy water plants; and renewable energy resources.

In the minerals sector CANMET scientists were involved in technical evaluation of mineral resources, technology development in mining, health and safety in mines, marginal mineral resources, mineral and metals processing, conservation of minerals and metals, environmental and materials development technologies, technology for the metal-casting industry, and administration of the Canada Explosives Act.

CANMET operates under a matrix management system whereby its Program Office interacts with line managers in planning, controlling and evaluating projects. Therefore, this review is organized according to program structure rather than functional units, thus bringing together related research activities of the branch's various laboratories: Energy Research Laboratories, Mining Research Laboratories, Coal Research Laboratories, Mineral Sciences Laboratories and Physical Metallurgy Research Laboratories.

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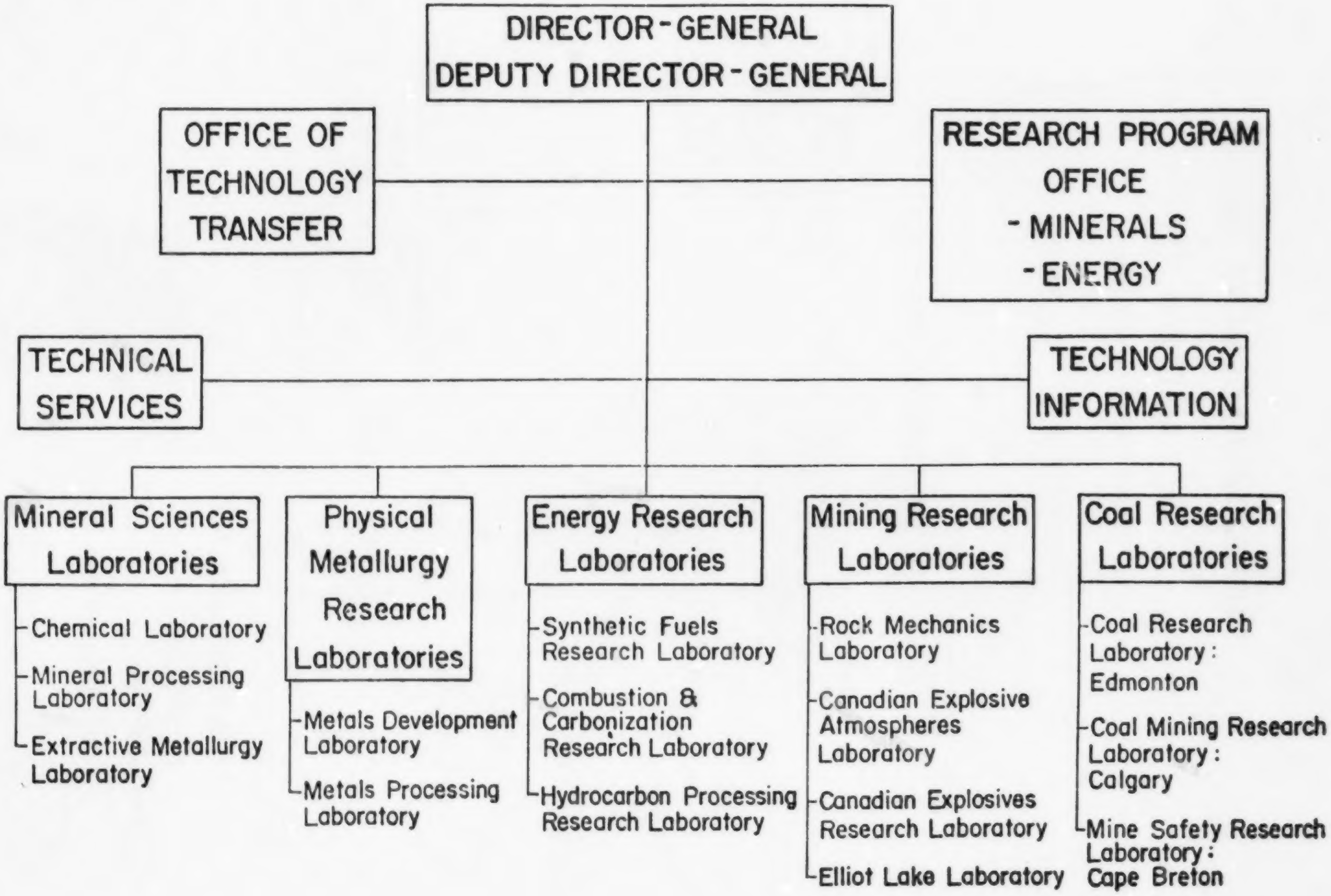
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Combustion & Carbonization Research Laboratory
Hydrocarbon Processing Research Laboratory
Mining Research Laboratories
Rock Mechanics Laboratory
Canadian Explosive Atmospheres Laboratory
Canadian Explosives Research Laboratory
Elliot Lake Laboratory
Coal Research Laboratories
Coal Research Laboratory: Edmonton
Coal Mining Research Laboratory: Calgary
Mine Safety Research Laboratory: Cape Breton

CANMET MANAGEMENT 1981-82

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Deputy Director-General — V.A. Haw

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Mineral Sciences Laboratories	W.A. Gow
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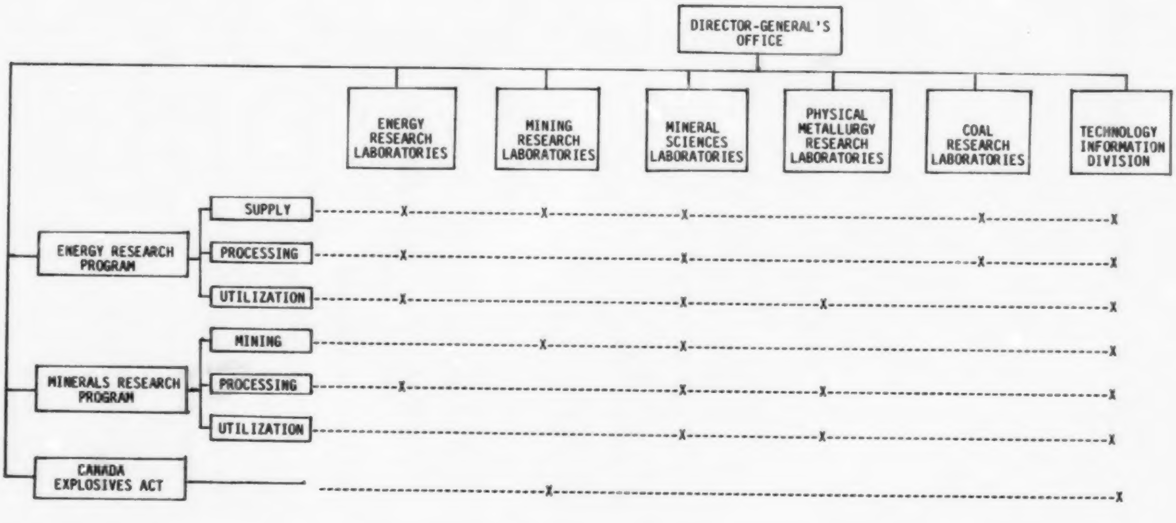
Physical Metallurgy Research Laboratories	W.H. Erickson
Coal Research Laboratories	T.D. Brown
Technology Information Division	J.E. Kanasy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ENERGY RESEARCH PROGRAM
SUPPLY
PROCESSING
UTILIZATION
MINERALS RESEARCH PROGRAM
MINING
PROCESSING
UTILIZATION
CANADA EXPLOSIVES ACT
X

DISTRIBUTION OF RESOURCES

1981-82

	PERSON YEARS	OPERATING FUNDS $ 000	CAPITAL FUNDS $ 000
ENERGY TECHNOLOGY			1,488
Conservation Technology	4	330	
Petroleum Supply Technology	68	3,647	
Coal Technology	112	5,199	
Nuclear Technology	33	1,058	
Renewable Energy Technology	10	395	
Research Program Office (incl. contracts)	6	3,008	
Information and Library Services	16	858	
Technical (Engineering) Services	34	1,222	
Management and other common services	50	693	
Grants and Contributions	--	301	
MINERAL TECHNOLOGY			745
Mining Technology	14	688	
Health and Safety in Mining	19	1,068	
Conservation and Resource Management	26	859	
Mineral Processing Technology	41	1,460	
Environmental Technology	22	894	
Materials Development Technology	39	1,467	
Metals Processing Technology	52	1,798	
Standards and Specifications	23	742	
Research Program Office (incl. contracts)	5	1,440	
Information and Library Services	21	961	
Technical (Engineering) Services	32	1,135	
Management and other common services	74	2,771	
Grants and Contributions	--	6	
ADMINISTRATION OF THE CANADA EXPLOSIVES ACT	12	458	29
TOTAL	713	32,458	2,262

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ENERGY RESEARCH PROGRAM

CANMET's energy research and development is chiefly concerned with improving the supply, processing and use of Canada's oil, gas, coal and uranium. The main objectives of energy research are directed to the goals of the National Energy Program and the government's priorities for economic development. Most of the work is related to fossil and nuclear fuels research where CANMET's expertise has always been concentrated.

The federal and provincial governments, industry and universities all cooperate in assessing the quality and extent of energy resources available in Canada. CANMET expanded its Energy R & D efforts under the National Energy Program by addressing the self-sufficiency thrust of this policy in keeping with its three priorities of developing alternatives to gasoline, increasing efficiencies of energy use, and developing new energy sources. CANMET maintains a close partnership with Canadian energy industries and electrical utilities by encouraging innovative R & D through cost-shared programs. The purpose is to try to develop further Canada's petroleum and coal based resources by improving extraction and upgrading technologies, as well as utilization of primary products. Increased emphasis on coal-related R & D was particularly significant following the consolidation of CANMET's regional coal research activities and establishment in 1982 of the new Coal Research Laboratories responsible for coal mining and preparation programs.

This review summarizes the activities, and describes the progress and achievements of fiscal year 1981-82. The Energy Research Program operated under the departmental activity: Energy Research and Technology Development, of which the objective is to contribute to the availability to Canada of technology for the supply, processing and use of energy to achieve sustained self-sufficiency as soon as possible. Further objectives are to assist in strengthening industry's competitive capabilities, and to provide leadership and liaison in dealing with other groups either at the international, provincial or industry levels.

The fundamental principle upon which planning foundation and frame of reference are based is that government sponsored R & D should be accessible to all Canadians and be undertaken to ensure the widest possible dispersion of its effects throughout Canadian society. In keeping with this concept, CANMET assumes the position of a public sector agency responsible for providing R & D under circumstances where the private sector cannot be expected to perform the services necessary for our society. Research planning at CANMET is based on this fundamental assumption, and along with the priorities of resource allocation, comprises the frame of reference for the planning and programming task and for the systematic project selection procedure developed for the Energy Research Program.

Strategic planning formulated within the scope of the Energy Research Program resulted in projects which focussed only on special technologies necessary to Canada in maintaining long-term energy independence and thus affecting critically the economic welfare of the country. The basic principles upon which this system was developed included economic efficiency with environmental consideration in determining priorities for energy resource development. Also it was established that public R & D should be carried out only where technology is an effective means of dealing with a particular energy issue relative to non-technological policies. The important connection between private enterprise and public management in the Canadian economy was acknowledged, and the least-cost principle would be applied in selecting technologies to avoid waste and maximize net benefits.

This review portrays the scope of the energy program which is presented in terms sufficiently broad to permit a range of technical approaches. Research projects are selected so they are most cost-effective in meeting a particular program objective. Although strategic objectives are developed to address Canada's future energy needs, the overall program also contains some essential elements which relate to maintaining a core science program. Chemical analysis and characterization capability is absolutely necessary for applied research and it will assume even more importance in identifying processing problems and determining product quality as we turn to alternative and lower-grade energy resources. In this perspective, the review emphasizes the significance of a number of technical achievements during the period especially regarding demonstration-scale projects in transferring technology and assisting in stimulating private industry in the development and commercialization of processes resulting from projects designed to assist Canada in attaining its energy goals. One major demonstration project which was particularly successful was the pilot-scale experimental work connected with the development and commercialization of the CANMET hydrocracking process. Petro-Canada announced the construction of a 5000 barrel-per-day demonstration plant costing $117 million at its refinery in Point-aux-Trembles near Montreal for upgrading heavy residual oils, with continuing research support from CANMET. The completion of the continuous-flow coal liquefaction bench-scale unit, and its promising initial results, placed CANMET at the forefront in developing coal-bitumen co-processing technology. Also, significant progress was made in the development of design criteria for chimney-less ultra-high efficiency gas furnaces for home heating; fluidized-bed technology for energy from low-grade coal; and coal-liquid mixtures for industrial oil furnaces. Carbonization research focussed on the development of technology to improve the quality of cokes produced by industry, and included a series of coking trials in industrial ovens in cooperation with the Algoma Steel Corporation. The CANMET coal liquefaction contract program, which is now in its sixth year, continued on the basis of federal government expenditures being divided between a shared-cost program with interested industrial participants and a 100%-funded program directed towards research projects of specific interest to CANMET. The main objectives of the totally-funded program are to develop Canadian interest and expertise in coal liquefaction and to generate a national database on the liquefaction behaviour of different Canadian coals. The overall objective of the shared-cost program is to contribute to the definition, research, development and demonstration of different coal liquefaction technologies in cooperation with private sector partners. CANMET provided expertise and technical advice on demonstration projects coordinated by other government organizations, including research on conservation and renewable energy technology.

Collaborative programs involving public and private sector cooperation through contracting, cost sharing and joint projects are becoming more important in energy R & D activities planned to support the policies of the National Energy Program. During 1981-82, 24% of Energy Research Program expenditures was applied to outside contracts to stimulate the private sector through continued involvement in energy research projects. CANMET continued playing an important role in international activities, especially in providing representation for the International Energy Agency and other international coal activities.

ENERGY SOURCES: SUPPLY, DEMAND AND SUBSTITUTION

The development of sound energy policies and effective resource management depends on the availability of the best information on the nature and extent of Canada's energy resources. CANMET participates in the assessment of reserves from the analyses of resource data derived from geological surveys and exploitation programs, through the application of resource quality parameters and technical and economic criteria to the information available. CANMET's many years of experience with coal and uranium and its expertise in mining have enabled its scientists to complete major projects on assessment of these energy commodities, in cooperation with departmental resource economists.

The assessment of the quality of indigenous resources of coal, peat, uranium and low-grade petroleum materials is the main objective of CANMET's research. Results assist in identifying research directions for optimum extraction, processing and utilization of these energy resources, as well as guiding decision makers in the development of energy policies. Research is concentrated on low-grade resources which could provide the bulk of Canada's future energy supply, but which require the development of special technologies for their utilization.

Resource Assessment of Petroleum-related Materials

The objective of Canada's energy policies is to achieve self-sufficiency in energy by eliminating its oil imports by 1990. Supplies from unconventional resources will have to be developed if these policies are to succeed. The extensive heavy-oil and oil-sand deposits of Western Canada are important potential sources of supply for liquid transportation fuels, which present the most urgent supply problem. CANMET supported the federal program in 1981 by continuing its lead role in applied R & D for the production of synthetic fuels from oil sands bitumen, heavy oils and coal. CANMET's Synthetic Fuels Research Laboratory received additional resources in 1981 for its alternative liquid fuels projects under the National Energy Program including both increased staff and funding. The main thrust of this research is to increase synthetic fuel yield during upgrading of bitumen and heavy oils in Western Canada and of residual oils in Eastern Canada through a substantial increased contribution from coals.

This resource assessment work is connected to the CANMET hydrocracking process for which the technology was transferred to Petro-Canada for use in its 5000 barrel-per-day demonstration plant at its refinery near Montreal. CANMET continued to support this activity by providing information for the scale-up and design of the demonstration plant for upgrading heavy residual oils. Catalyst research projects for evaluating the various feed-

Researchers (L-R) D. Patmore, R. Beer, J. Denis and M. Pleet examine print-out from test run of pilot reactor for CANMET hydrocracking process

Researchers D. Patmore (L), and M. Pleet (R) discuss operation of CANMET's hydrocracking 1-b/d pilot plant with plant operator A Kuiper

stocks for the CANMET process and projects for the chemical characterization of feedstocks and their products contributed significantly to this major success. CANMET completed a continuous-flow coal liquefaction bench-scale unit at its Energy Research Laboratories. Initial experiments undertaken to investigate the co-processing of coal and bitumen produced very encouraging results.

The Oil and Gas Analytical Laboratory reported 14 800 analyses on 3900 samples. The majority of the projects involved analytical support of the bitumen refining projects, including routine and non-routine analyses of gaseous, liquid and solid samples from CANMET's own research. Other work involved analyses of crude oils and natural gases from the province of Ontario and contract work for the New Brunswick Electric Power Commission. Mine atmosphere samples from provincial inspection agencies and various exchange and standardization programs were also analyzed.

Coal and Peat Resources and Reserves

CANMET's work on Canada's extensive coal and peat resources is to assess the recoverable reserves together with the production capability of the industry and to assist in documenting and developing the use of Canadian coal in both the domestic and export markets. Coal reserve assessment work was reinstated by Mining Research Laboratories' staff and the results will be published biennially beginning in 1981/82. A major achievement during the year was a clearer definition of the purpose for this work within the department pending the announcement of a national coal policy. Field trips were made to both operating coal mines and developing coal properties for purposes of data acquisition and current awareness. CANMET maintained liaison with provincial government regulatory agencies especially in Alberta and British Columbia since they are valuable sources of data and information. A report "Coal reserves and production in Canada: 1981" was prepared which provides data on coal reserves, coal production, and geostatistical methodology for deriving reserves from the SASCO file, using a trial area in southern Saskatchewan.

CANMET compiled a fourth supplement for the "Analysis directory of Canadian commercial coals" which included for the first time analyses of sulphur forms, especially useful in assessments of limits of sulphur removable by conventional coal preparation. While the Point Edward Regional Laboratory was being transferred to Sydney, Nova Scotia, the Ottawa Analytical Laboratory maintained close participation with the Nova Scotia Department of Mines in the continued federal-provincial coal resource assessment program. A contract to investigate the feasibility of using wet air-oxidation technology for dewatering peat and even for generating steam using peat as a fuel has produced encouraging results. CANMET's new Coal Research Laboratories assumed responsibility for participation in coal resource and reserve assessment at the end of 1981-82. Also, the National Research Council funded under the National Energy Program assumed responsibility for promoting and developing peat as a potential fuel in Canada.

Uranium Reserves and Production

The Mine Evaluation Group at CANMET's Mining Research Laboratories (MRL) prepared its comprehensive annual internal report for the departmental Uranium Resource Appraisal Group (URAG) based on a continuing assessment of measured and indicated uranium reserves and resources in Canada. The objective is to apply engineering and economic criteria to establish mineability and productive capacity of existing and projected Canadian uranium producers and the viability of potential new operations. CANMET's mining experts are improving existing methodologies and are developing new, more sophisticated methods for assessing uranium reserves and resources. These methods are being designed to utilize effectively the large quantities of primary data supplied to the Mine Evaluation Group on all economic uranium deposits in Canada. MRL staff provided leadership to the Subcommittee on Reasonably Assured Resources (Measured and Indicated) and is represented on the Subcommittee on Estimated Additional Resources (Inferred, Prognosticated and Speculative).

URAG assisted the Ontario Ministry of Natural Resources in 1981 in a project to evaluate the uranium resource potential of the south limb of the Elliot Lake Syncline on the basis of several mining cutoff grades. This evaluation enabled the ministry to prepare economic forecasts on the province's nuclear resources considering different future economic climates. The Mine Evaluation Group completed a confidential report containing a description of the method used and the study results. It was submitted to URAG, the Ontario Ministry of Natural Resources and Rio Algom Ltd., owner of the uranium mining properties investigated. CANMET continued to collect primary data for analysis from uranium mining and development companies to formulate computer processible data files for use as primary information sources for the Mine Evaluation Group's resource evaluation. CANMET's mineral processing specialists participated in the work of URAG to assess the productive capacity of Canada's uranium mines and mills.

ENERGY RESEARCH AND TECHNOLOGY DEVELOPMENT

Canada's future energy requirements, according to the objectives of the National Energy Program, are to change from traditional dependence on conventional crude oil to a new mixture of alternative, more flexible sources of supply. The pre-conditions to initiating new sources of supply require that economic viability and technological feasibility be established before they become practical alternatives. The priorities with regard to using non-conventional sources are directed toward development of technological options to support sustained self-sufficiency in energy requirements by concentrating R & D on the most economically significant energy alternatives. Also this research will have priorities of minimizing hazardous effects of conversion processes, as well as diversifying sources and technological routes to enhance flexibility, especially in seeking alternatives to conventional liquid fuels. Completely new or extensively modified technology will be needed in many cases to convert difficult or variable feed stocks to products that meet domestic specifications - taking into consideration the long lead time implied. These priorities, together with the traditional policies of resource development in Canada, are the principles that direct energy research and development to obtain for Canada energy self-sufficiency, especially in liquid fuels.

Conservation Technology

Canada must make the best possible use of the resources we are now consuming if we are to meet national energy goals. CANMET continued its detailed research on technological innovations that can enhance the efficiency of fuel-burning equipment. This research work is coordinated with the energy conservation efforts of many other public and private sector organizatons.

Road Vehicle Economy - A summary is now being prepared of the results of a nine-year program undertaken by CANMET to study the effects of Canadian climate on automobile fuel consumption, involving both road and dynamometer trials in temperature-controlled environments. Tests on vehicles having conventional engines, simple carburation and relying solely on an oxidation catalyst to meet emission regulations have shown that fuel economy and emissions degrade rapidly with decreases in ambient temperatures. Advanced combustion designed engines such as high speed diesels, stratified charge, lean burn, or other computer systems to control combustion performance degrade much less with respect to both fuel economy and emissions. When these results were reported to the Society of Automotive Engineers, Chrysler Canada submitted an unsolicited proposal to improve engine technology for Canadian winter conditions. Recently completed Phase I modifications include an early fuel evaporation configuration, an engine block heat retention package and a high compression configuration with optimized spark control. Fuel economy was improved 20% over the first portion of the cycle, and 6% overall at -20°C, relative to the 25°C baseline. Stabilization times were reduced 40% relative to the base configuration, for the block heat conservation configuration, yielding fuel economy improvements of 8% on the city cycle and 9% on the highway cycle, at 25°C. The optimum electric block heater preheat time was 2.5 h at -20°C, giving a fuel economy benefit of 10% over the city cycle. The high compression configuration, with a unit increase in compression ratio, decreased fuel consumption by 4 to 8% at all test temperatures.

Domestic Oil Furnaces - CANMET has conducted applied research for the past 11 years on the most effective techniques for improving the performance of oil-fired domestic heating systems. Additional detailed studies were made on a number of Ottawa area homes which allowed instrument monitoring of actual seasonal variation in heating system performance. It was found that major efficiency gains were realized by retrofitting an existing conventional burner with a flame retention head. This procedure allowed significant reductions in excess air and flue gas temperature, resulting in efficiency improvements from 12 to 18% in both laboratory and field tests. Furthermore, only a minimal number of components had to be changed on the existing burner. Firing rate reductions of over 25% are possible using this new head without loss of control of combustion air or fuel/air mixing. Additional fuel savings from 5 to 10% are possible as a result of downsizing the heating system this way, to make the furnace output more compatible with the heat demand of the dwelling.

A survey of the performance of domestic oil furnaces was carried out in 14 Canadian cities resulting in data on 15 000 homes. Steady state efficiencies were determined from measurements of carbon dioxide and stack temperature. Readings were taken and recorded on draft and smoke number, along with information on the make and model of furnace and burner, fuel and electrical consumption, house characteristics and demographic data. Results showed that the average excess air was 100% corresponding to a carbon dioxide level of 7.5% and a steady state efficiency of 74.5% indicating good potential for improved performance with retrofit flame retention heads.

Domestic Gas Furnaces - CANMET is conducting research on domestic gas-fired heating systems aimed at developing and determining the performance of some of the most promising new technologies, under both controlled laboratory and actual field conditions. Performances of a number of condensing furnaces, either in the prototype or marketing stages are being evaluated to improve the efficiency of present units and to make design modifications or improvements. Conventional gas-fired heating systems operate at a seasonal performance efficiency of approximately 55 to 60%. Seasonal efficiencies of more than 90% can be achieved through significant reductions in fuel consumption effected by technological changes by improving combustion performance, reducing off-cycle losses, eliminating the need for downstream infiltration through the draft hood and condensing some of the water vapour present in the flue gas to regain its latent heat.

Conventional natural gas furnaces have a lower efficiency than conventional oil furnaces because the relatively high hydrogen content of natural gas results in larger latent heat loss including that portion of the sensible heat carried by the water vapour. Also, this high hydrogen content can result in potential localized condensation and corrosion within the conventional heat exchanger. Manufacturers designing equipment using natural gas and propane containing very low levels of sulphur associated with high levels of moisture in their flue gases have tried to overcome efficiency loss when using gaseous fuels by condensing this vapour and regaining much of the heat within a specifically-designed heat exchanger.

The loss of heated house air (dilution air), which is entrained with the flue gas through the draft hood of a conventional gas furnace can also be a problem. This dilution air, for most installations, represents a major loss of warm air up the chimney, while the furnace is operating, and it can represent an air supply problem in an airtight house.

Low-Calorific Gas Burner Development - The development and field testing of the low Btu gas burner has been completed, reported, and patent application initiated by CANMET. Industry enquiries on its use for wood gasifiers, B.F. gases, etc., are being referred to the contractors and developers, the Canadian Gas Research Institute. Novel features allow it to use hot, dirty gas from coal or wood gasifiers. Normally, gases are cooled to remove tarry matter prior to burning, but this results in significant energy loss due to the removal of both sensible heat and the calorific value of the organic condensibles.

Electrical Energy Storage Devices - CANMET continued applying its expertise in materials science by developing technology through intramural research for the fabrication and exploitation of various solid state electrolytes in energy storage and conversion systems, and by demonstrating their most promising applications through technology transfer. One phase of research focussed on the production of durable sodium beta-alumina under pilot-plant conditions and examining the nuances of compositional and processing variations on its performance in the laboratory. During 1981-82, laboratory research determined the effects of composition and crystallographic orientation on the thermal conductivity of the sodium beta-aluminas from 150° to 650°C. As a result, a contract to develop solid electrolytes and demonstrate their performance in a thermoelectric generator was successfully concluded in the production of highly conductive material on a small pilot-plant scale and in the fabrication of the material in a novel design of generator for which sputtered molybdenum had to be developed. The contractor recently initiated a three-year program to scale up to 20-kg batches of material and to demonstrate its performance in recovering power from the companies stack gases.

CANMET continued conducting and sponsoring research on other electrolytes used in electrical storage and conversion devices. Work continued on the development of zirpsio ceramic materials, examination of which showed them to be strong competitors for applications envisaged for the beta-aluminas such as advanced batteries, thermoelectric generators, sensors and pumps. Their appeal lies in their three-dimensionally conducting character compared with two-dimensional beta-aluminas, their claimed ease of synthesis, and their high ionic conductivity. In addition to the zirpsios, two other groups of materials known as gasicons and yasicons, are known to be three-dimensional conductors and have conductivities comparable with those of beta-aluminas. Research showed that good quality, highly conductive materials can be produced, but the conductivity is not significantly increased by substitutions. The possibility of devitrifying a pre-shaped glassy body by annealing was unsuccessful as a relatively non-conductive material tended to crystallize out first. Also, the product tends to be microcracked because the crystalline phase has a higher specific volume.

Examination of a method for non-destructive evaluation of solid electrolytes showed that cracks and pores in an electrolyte in service can initiate failure by promoting the growth of macrocracks. Consequently, it is anticipated that quality control procedures suitable for production-line use will be required to assess the extent of sub-surface damage. The production of transducers based on lead zirconate-titanate was examined and thin films of poled PZT were produced by mechanical lapping and sputtering. The advantage of the latter is the ease of producing a thin piezoelectric film in a wide range of shapes that produce either focussed or parallel ultrasonic beams.

A successful correlation was made between the nuclear magnetic resonance spectra and the ionic conductivity of various sodium-conducting electrolytes. Also, the behaviour of the hydrogen analogues was studied, and a practical aspect of this work is the anticipation of being able to have a very simple and rapid assessment of the conductivity of sintered material on a production line without the usual time-consuming procedures. One interesting spin-off from this work appears to be the potential of assessing the conductivity of material of any arbitrary shape using a non-contacting method that can be achieved in about 15 seconds on a production line at very low cost.

Hydrogen by Photoelectrolysis - The objective of this project is to develop semi-conductor materials for solar energy conversion to electricity or hydrogen by direct photoelectrolysis of water. Basic studies were conducted on the interfacial properties at the flat-band potential, zero point of charge, the reversible double layer, adsorption, and the distribution of potential. The materials investigated were molybdenum sulphide, titanium dioxide and gallium arsenide, on which measurements were made to determine photopotentials, spectral response and short-circuit photocurrents. Kinetics and charge transfer mechanisms of redox reactions on semiconductors were investigated in relation to electrode stability and photocorrosion. Energy level diagrams for the semiconductor-electrolyte interfaces were constructed on the basis of experimental results, and energy conversion was studied.

Applied investigations included the development of oxide and sulphide semiconductors with low band gap and modification of the solid properties of titanium dioxide to reduce the band gap and improve light absorption properties. Other achievements included development of oxide and sulphide semiconductor films, development of n-type and p-type gallium arsenide and gallium phosphide films, as well as optimization of solid state properties to improve efficiencies. Single crystals of molybdenum, titanium and zirconium sulphide also were prepared and used for the preparation of photosensitive electrodes in order to study their photoelectrochemical properties.

In a collaborative program supported by CANMET, Bell Northern Research prepared semi-conducting films of titanium dioxide by a screen printing technique. The photoelectrochemical investigations were carried out at CANMET laboratories to determine the effects of particle size, sintering and reduction temperatures, duration of sintering, and film thickness and structure, on film performance and photoanodes. Also, the optimum parameters for film fabrication were established. These films showed a larger percentage absorption of light than single crystal titanium dioxide and the overall efficiency for conversion of solar energy to hydrogen was about 3.5% with 240 mV bias and 3% without bias at pH 13. The film printing is simple and can be scaled to large-scale preparation. Attempts are being made to improve the energy conversion efficiency of these films.

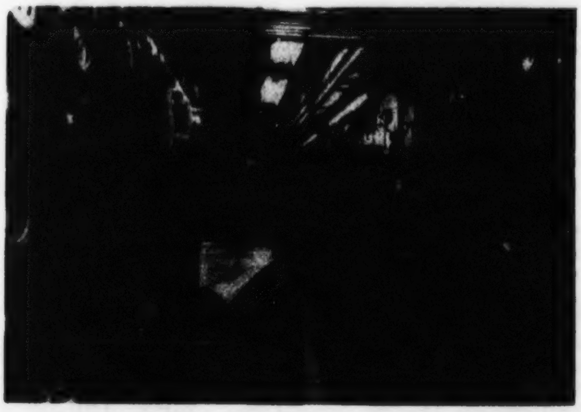
Collaborative research supported by contract with McGill Industrial Research was started on the preparation of opitactic gallium arsenide films on different substrates. The photoelectrochemical investigations will be carried out at CANMET to develop n-type and p-type gallium arsenide films on cheap substrates, having high efficiency and stability to photocorrosion, and which can be used as photoanodes and photo-cathodes, respectively, in photoelectrolysis of water.

Petroleum Supply Technology

The general objectives and strategic long-term objectives of CANMET's research in petroleum supply technology is to develop and demonstrate new, improved technologies which will overcome the technical constraints for the exploitation of Canadian petroleum resources and the integration of synthetic fuels derived from bitumen/heavy oils into the end-use system. The challenge of developing methods to improve recovery of synthetic petroleum from Western Canada's huge resources of bituminous sands and heavy oils has always been especially interesting to CANMET's researchers. The objective is to develop improved technology for catalytic conversion of asphaltenes to liquids, and to establish upgrading processes to increase liquid product yields so they can be used as refinery feedstocks. The development of the CANMET hydrocracking process and the transfer of this technology to industry for commercial applications was a major achievement of this program.

Bitumen and Heavy Oil Recovery - The in situ recovery of oil using steam-flood or fire-flood methods yields relatively stable water-oil or oil-water emulsions containing a high or low percentage of the inner phase. The oil and water phases must then be separated as cleanly as possible for environmental, economic and technical reasons. The objectives of a new project supported by two oil and two chemical companies included monitoring of changes in wellhead production with changes in operating conditions, evaluation of demulsifiers and optimization of demulsification conditions for the suitable reagents. Another stage of development and application of quantitative methods for oil-in-water and water-in-oil analysis was completed. Some reagents, tailor made by the participating chemical companies on the basis of the earlier experimental work were found to be very effective as demulsifiers.

Bitumen/Heavy Oil Upgrading - Research on process development was carried out to supply information necessary for the design of a CANMET hydrocracking demonstration unit for upgrading bitumen and heavy oil. A series of pilot plant runs was carried out

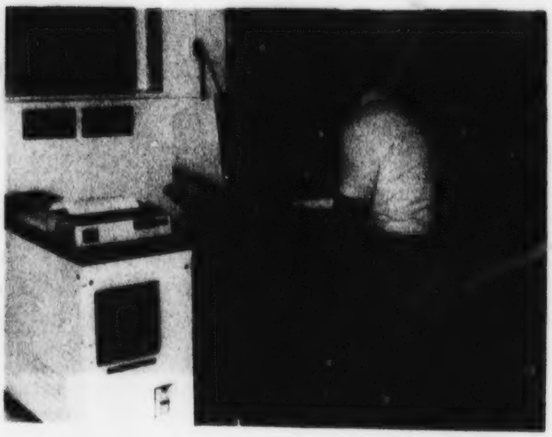


Plant operators R. Eagleson, M. Boyle and R. Lycett work in the control room of CANMET's hydrocracking pilot plant with project leader T. de Bruijn to characterize various types of feedstocks and to obtain information on the effect of operating conditions on product yields and fuel properties. Additional runs were performed to determine long-term operability of the CANMET process using residual heavy oil. Pilot plant operation for 1981-82 amounted to more than 6000 h.

Work was also carried out using bench-scale and autoclave units to support the pilot-plant work. The bench-scale continuous unit was used for a preliminary assessment of the safe operating range for new feedstocks, while batch autoclave experiments were designed for additive assessment.

A program aimed at characterizing additive solids from the CANMET hydrocracking reactor was continued during 1981-82. These projects included electron microprobe studies, scanning electron microscopy, back-scatter electron microscopy and particle size distribution measurements.

Characterization of Bitumens, Heavy Oils and Processed Products - As Canada's energy policies are directed primarily toward eliminating its oil imports by 1990, research activities focussed on developing supplies from unconventional resources, with applied R & D continuing for improving production of synthetic fuels from oil sands bitumen, heavy oils and coal. CANMET provided analytical support of the bitumen refining projects, including routine and non-routine analyses of gaseous, liquid and solid samples, for both in-house and outside projects. Some of the work involved analysis for various agencies, including crude oils and natural gases from the Ontario government, contract work for New Brunswick Electric Power Commission, and mine atmosphere samples from provincial inspection agencies and various exchange and standardization programs.



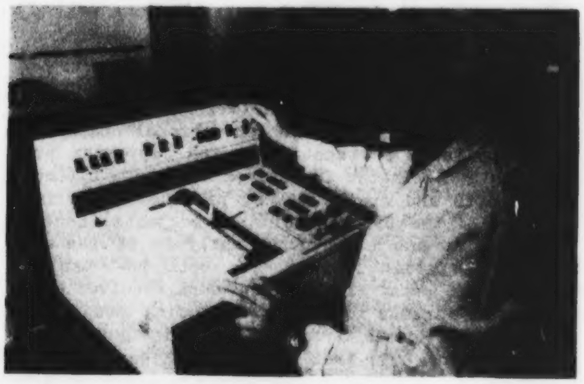
Technologist B. Casault of PMRL uses image analyzing computer "Quantimet 900" for quantitative measurements of microstructural constituents in pressure vessel weld overlay material

Plant operator P. Landry tends pilot plant reactor for CANMET hydrocracking process

Characterization research deals with chemical analysis to determine hydrocarbon, sulphur and nitrogenous compound-type distribution of bitumens, heavy oils and their processing products. The work involves development of rapid procedures for the analysis of middle distillates and their residual fractions. Investigations relating the chemical composition of diesel fuel oils to their combustion characteristics were initiated in an attempt to simulate cetane number determinations in the laboratory.

This research focussed on developing methods for the removal of nitrogenous components from synthetic fuels using inexpensive materials of Canadian origin. The fourth in a series of patent applications on the subject was submitted to Canadian Patents and Development Limited. The characterization of nitrogenous components in synthetic fuel products was equally important. The effect of hydrocracking by the CANMET process on the distribution of these compounds in a Venezuelan oil was investigated. Nitrogenous components are important because they cause catalyst deactivation in upgrading processes. Chemical composition deter-

G. Smiley, technologist, operates high resolution gas chromatograph to analyze heavy oil and bitumen



H. Barber, technician, uses infrared spectroscopy to examine a heavy oil fraction

minations of the various components in the feed and products from various stages of processing severity from catalytic and thermal hydrocracking were made. A heavy oil provided by a potential client for the CANMET hydrocracking process was studied. A study on the effect of changing hydrocracking conditions on the sulphur-type distribution in the naphtha of a Venezuelan oil is underway.

A method was developed for rapid compound-type analysis of diesel fuels using high performance liquid chromatography. Considerable progress was made in methodology development for rapid determination of asphaltene content using thin layer chromatography. This method, when completed, can provide a viable substitute to the time-consuming standard procedure. An apparatus was built and initial testing was carried out to simulate cetane number determinations for diesel fuels in the laboratory.

M. Curtin, cooperative student, separates heavy oil and bitumen using preparation-scale liquid chromatograph

Catalyst Development for Bitumen/Heavy Oil and Product Upgrading - Achievements in catalyst development included improvements in catalysts for commercialization of CANMET hydrocracking technology. The purpose of some of this research was to reduce catalyst costs by developing cheap disposable catalysts and by improving the longevities of conventional catalysts for hydrocracking, desulphurization, denitrogenation, and hydrogenation. The results of these experiments and those carried out to evaluate feedstocks for CANMET hydrocracking under cooperative agreement with Petro-Canada are proprietary information.

Development of Improved Catalysts for Hydrocracking and Hydrotreating - Part of this research activity was devoted to evaluating carbon monoxide as a hydrogen extender in hydrocracking bitumen, Phase III. Phase I and II had been completed previously and dealt with mixtures of hydrogen and carbon monoxide in the presence or absence of a commercial hydrotreating catalyst. Phase II included tests involving several other catalytic systems. The need to remove carbon monoxide from hydrogen steam has important economic consequences in both mega-scale and refinery-scale upgrading operations. It would be economically beneficial to bypass gasification and shift-conversion steps, if this procedure were acceptable technically. The career oriented summer employment project research program consisted of experimental tests using Athabasca bitumen in a continuous-flow, high-pressure fixed-bed bench-scale reactor system. Pure hydrogen and a mixture of 50% carbon monoxide in hydrogen at 1000 and 2000 psig were used for testing three individual catalysts, at three different temperatures. The project results were presented at the 20th IUPAC Congress in Vancouver in 1981, but the report scheduled for completion in February 1982 has been delayed.

The data obtained for mixtures of carbon monoxide and hydrogen were compared with those for pure hydrogen used in hydrocracking Athabasca bitumen. The comparison indicated that thermal hydrocracking was largely unaffected by the presence of carbon monoxide provided hydrogen was present in sufficient amounts. The same applied where hydrogenation catalysts were present enabling operation at a higher temperature. The effect of a cobalt-molybdenum catalyst on the other hand, was severely impeded by the presence of carbon monoxide and increasingly so with increased concentrations. Therefore, it was not appropriate to use cobalt-molybdenum catalysts which conflicts somewhat with the findings of researchers at the Pittsburgh Research Centre for hydroprocessing of coal.

A comprehensive study at the Pittsburgh Research Centre on coal liquefaction with synthesis gas in autoclaves covered different ranks of coal and a variety of operating conditions. The detrimental effect of carbon monoxide on cobalt-molybdenum type catalyst has not been indicated, however, some catalyst modifications leading to improved conversions, such as addition of potassium carbonate were shown. The effect of water addition (COSTEAM upgrading) in selected cases will be investigated in the near future.

An investigation focussed on the development of additives with improved effectiveness in primary upgrading of heavy feedstocks by hydrocracking. The method used for evaluating feedstocks can be used equally well for additives or catalysts in connection with hydrocracking a particular feedstock. Tests which were planned on silica and alumina-based additives were delayed by failures in reactor heating systems and a major pump apparatus. Experimental tests involving silica-based additives included an investigation of the effect of silica-gel pretreatment on silica support porosity. The silica support showed improvement over alumina support in connection with reactor coke suppression at higher temperatures but the refining capability of silica-supported additives was found to be less. An interesting phenomenon observed in connection with porosity variation indicated that coke suppression capability is improved by increasing the average pore size in silica.

Catalyst deactivation is one of the most important problems to be resolved in petroleum processing. It has a limiting influence on the interval of continuous operation, operating conditions and product quality. Catalyst evaluation is usually not considered complete without a long-range deactivation test. During most of 1981, continuous catalyst testing consisted of constructing a four-reactor unit capable of semi-automatic continuous operation with limited supervision. After construction was completed at year end, several exploratory runs were performed involving both commercial and experimental catalysts.

Large pore structure is necessary to expose the internal surface of catalysts to large molecules present in heavy oils and bitumens. Specific pore volume, average pore size and internal surface area are inter-related. Successful developments in the past have shown that it is possible to increase significantly both porosity and the average pore size of alumina while maintaining sufficiently high surface area. This was achieved by special pretreatment procedures. CANMET started recently the further development of catalysts and catalyst supports having high porosity.

Heteroatom removal from coal-derived liquids involved evaluation of the upgrading of coal-derived liquids and study of catalytic hydrogenation of model phenolic compounds. There are important chemical differences between fuels derived from natural crude oils, heavy and residual oils or coals, but they all require refining to meet specifications for consumption. As existing refineries are designed to process natural crude oils, the particularly uncertain qualities of the coal liquid must be assessed to determine if their processing requirements are compatible with present systems.

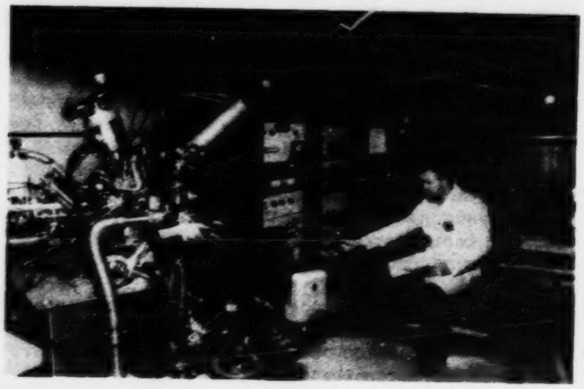
Distillate liquid product from Canadian sub-bitiminous coal produced by hydroliquefaction was catalytically hydrotreated. CANMET released the results in a report and at a conference presentation. A laboratory apparatus to study hydrodeoxygenation was constructed during 1981. The hydrotreating of coal-derived distillates was assessed for typical conditions of a commercial hydrotreater. Researchers performed comprehensive analyses of the hydrotreated product and determined reactivity trends of various compound types. Coal liquids were found to be extremely difficult to refine compared with petroleum liquids having similar physical properties. Problems apparently resulted from the presence of oxygen containing linkages and functional groups. Under partly funded contracts, Algas Resources Ltd. produced the coal-liquid sample and SNC Inc. prepared a nine-volume technical assessment of coal liquefaction processes.

Research on hydrotreating distillates is of great importance to Canada. The objectives of this work are the conversion of aromatics to improve quality of diesel fuels from Athabasca oil sands, and the assessment of distillates from a refinery residual oil converted by the CANMET hydrocracking process. Diesel fuels from Athabasca oil sands are of poor quality because of the excessive presence of aromatic compounds in middle distillate fractions. Although these products can be hydrogenated, its effect on diesel fuel quality cannot be easily predicted. Catalysts and operating conditions must be carefully selected to optimize diesel fuel production. An assessment of CANMET distillates must be carried out in connection with Petro-Canada's demonstration plant near Montreal.

CANMET completed a report in 1981 on the impact of excessive aromatics in oil sand syncrudes, based on information from both a literature survey and personal communications with experts.

In 1981, seven different batches of additives were prepared for pilot-plant testing and characterization by the Catalysis Section of the Energy Research Laboratories. One contract each was awarded for development of catalysts for hydrogenation of aromatic compounds to Guelph Chemical Co. and to SNC Inc. One each of two projects to assess the feasibility of proposed desulphurization processes for hydrocracked pitch was contracted to SNC Inc. and W&Y Consultants Kingston Ltd. The desulphurization of pitch before its combustion is necessary to prevent either excessive sulphur dioxide emissions or expensive flue gas desulphurization. Reports on pitch desulphurization are completed and those on hydrogenation catalyst development are expected in 1982. Researchers at SNC Inc. determined that hydrocracked pitch can be desulphurized to an extent by reaction with phosphine gas and recycled solvent. Although SNC assumed that phosphorus could be recovered, an assessment of process feasibility could not be provided. W&Y Consultants Kingston Ltd. determined that hydrocracked pitch can be effectively hydrodesulphurized by application of microwave field, and metal/metal hydride catalyst with hydrogen at atmospheric conditions. The process is being patented. This contract is also being extended to provide more experimental and analytical data and to address some aspects of reactor design. Since this method has possible applications in coal gasification and hydrotreating liquids, fundamental research is being funded through the National Research Council and the Alberta Oil Sands Technology and Research Authority.

The new X-ray photoelectron surface spectrometer was used to characterize molybdenum-cobalt-alumina catalysts during reaction with H_2S/H_2 and thiophene/H_2. The catalyst in the sulphided state converted thiophene to C-4 type hydrocarbons. Two species of molybdenum and elemental and sulphide sulphur were identified on the surface of the sulphided catalyst. CANMET's results agree with those of other studies suggesting that at least two types of molybdenum are present. Advanced instrumentation options have been purchased for the new spectrometer which will contribute significantly to its capability. Research was started to examine coal by XPS with the aim to monitor oxidation of mineral components and organic constituents in studying the characterization of coals for cokemaking. Projects are in progress to examine the mechanism of oxidation of coking coals.



Technician L. Galbraith operates multi-technique analytical surface spectrometer having X-ray photoelectron, ultra violet photoelectron and auger electron spectroscopic capabilities - hydrotreating catalyst and coal surfaces can be analyzed for pertinent chemical information

Materials for Oil Sands Processing - CANMET metallurgists are studying ways to minimize the overall wear on equipment used in oil sands processing due to abrasion and corrosion processes resulting from transportation of large quantities of abrasive raw material and waste. Suitable wear resistant materials must be developed and guidance provided in selecting materials for equipment. The results of laboratory tests showed that at high velocities of transporting sand-water slurries the use of abrasive resistant steels might be beneficial when corrosion rates are low. On the other hand, when corrosion contributes to the overall wear as is encountered in turbulent tailings slurries, the use of corrosion resistant materials will be preferable. The final choice will depend on economic evaluation of initial capital costs of construction versus extended life benefits through lower operating costs.

Materials for Oil and Gas Pipelines - Exploitation of Canada's northern oil and gas resources will require pipelines made from controlled rolled high-strength low-alloy (HSLA) steels having superior low temperature toughness. This has resulted in extensive evaluation of overall sections of commercial linepipe from different manufacturers by examining metallurgical uniformity and isotropy through impact and tensile properties, and by chemical and corresponding optical quantitative microstructural analyses. Significant variations in microstructure and properties were observed within a single section of linepipe, demonstrating the need for precisely defining test locations. Important correlations between toughness and microstructure have been shown for both ductile and cleavage fraction modes. The toughness correlates well with the largest polygonal ferrite grain size. Recent analysis of these results has focussed on the relationship between delamination frequency in Charpy specimens tested at various temperatures and microstructural features. The unique facilities afforded by CANMET's Physical Metallurgy Research Laboratories (PMRL) of steel melting and instrumented controlled rolling have provided the opportunity to further develop linepipe HSLA steel metallurgy in support of the Canadian pipemaking industry.

Leaner alloy chemistries, lower processing temperatures, higher strength grades and thicker plate gauges have all demonstrated the need to tailor the steel and processing to the available equipment. Fluctuating alloy mix costs, in particular molybdenum, have shown the need for an understanding of the separate and synergistic effects of alloying elements in order that alternative chemistries may be chosen as alloy costs increase. The separate and synergistic effects of chromium and vanadium are being studied on a simple pearlite-reduced steel. Mechanical property measurements are two-thirds complete on 11 different compositions. Steels have been made ready for studies of mill loads and microstructural changes occurring during roughing. At a later stage it is hoped that this work can be related to that being done under contract by McGill University on the effects of alloying elements on the kinetics of recrystallization and precipitation. The influence of finish rolling temperature has been studied by comparing mechanical behaviour and microstructural features of plate finished at austenite temperatures with that finished at the austenite/ferrite temperature range. The through-thickness fracture properties deteriorated with the lower finish rolling temperature due to both increased ease of microcrack nucleation at inclusion arrays and to preferential cleavage crack nucleation in the large ferrite grains parallel to (001); at the lower finishing temperature, there was more pronounced (001) preferred orientation parallel to the rolling plane.

Pipelines are subject to mechanical damage during installation and to several electrochemical related degradation mechanisms while in service, which can result in their premature failure. Research is being conducted to ascertain what degree of mechanical damage can be accepted, what level of residual stresses can be tolerated and how the effects of electrochemical attack can be mitigated.

During pipelaying, dents and gouges can be produced by earth moving equipment and by rocks and debris in the trench. Experimental work on the effect of dents having different shapes and severities on fracture initiation in pipelines has been completed. Dents having gentle curvature can be pushed out close to their original contours during pressuring. The hoop strain can be over 15% yet no crack is initiated either during initial pressurization or during subsequent fatigue loading. Dents with sharp curvature cannot be removed during proof testing and while the hoop strain is low during initial pressuring the strain concentration can be more than three times larger, leading to subsequent crack initiation during fatigue testing. A theoretical elastic-plastic analysis of the state of deformation of a pipe having a dent has started. This work is the first of a series of studies aimed at quantifying the effects of mechanical damage on fracture initiation in pipe using the finite element method.

Flattened specimens with a machined notch or scraped gouge were tested at the start of an investigation of gouge effects. Machine notched specimens failed at the notch during both tensile and fatigue testing. Gouged specimens failed at the gouge only in fatigue tests, unless the gauge caused a thickness reduction of more than 20%, in which case they also failed in tension.

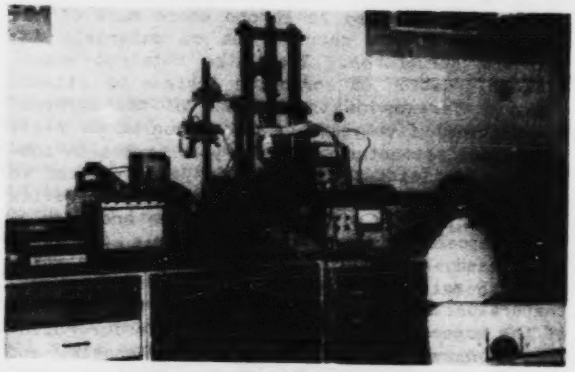
Pipeline failure is possible through unintentional overload caused by applied and residual stress acting together. Residual stress from the pipe-forming and expansion operation can reach 50% of yield stress. Measurements of residual stress using different techniques were completed. Residual stress measurements by strain gauge methods on commercial pipe have been summarized in one report, and a second on stress measurements of the last spiral weld pipe evaluated is in preparation.

Stresses can change during pipeline service due to earth movement, e.g., washouts. A contract was awarded to Queen's University to measure the effect of stress on magnetic parameters in pipe steel. Attempts will be made to correlate laboratory measurements with magnetic measurements made in the field by a pipeline company.

Linepipe steels are subject to cracking in the presence of hydrogen sulphide (H_2S) from sour oil or gas. Two forms of H_2S-induced cracking - sulphide stress cracking (SSC) and stepwise cracking (SWC) - are under investigation. Sample testing of nine gas transmission pipes covering grades 290-483 is two-thirds complete. Standard test methods for susceptibility to SWC and SSC developed by the National Association of Corrosion Engineers are being used. The results are now being assessed to determine the operative cracking mechanisms and their relevance to sour service performance.

Stress corrosion cracking is another failure mechanism which is attributable to soil-borne ions attacking a coating break. Using the slow-strain-rate tensile testing machine and teflon electrochemical cell designed and built at PMRL, the electrochemical potential ranges in which linepipe steels stress corrode in nitrate and carbonate bicarbonate solutions at 40°C and at strain rate 10^{-6}/s have been defined.

Assessment of the properties of mill welds in commercial linepipe and its field weldability continues as an important aspect of the evaluation work. Field weldability and implant tests were done on the most recent section of spiral weld linepipe. Results indicated satisfactory weldability and only moderate sensitivity to hydrogen cracking in the field weld heat-affected zone when compared with a similar steel previously tested which had no inclusion shape control. However, the seam weld metal toughness was inferior in the linepipe made from steel with sulphide shape control. This phenomenon is being investigated further.



Technologist R. Ramsingh tests susceptibility of linepipe steel to stress corrosion cracking by slow strain rate technique

The notch toughness of regions within the seam weld heat-affected zone is difficult to determine because the microstructure and properties change abruptly over short distances. The coarse-grained heat-affected zone (CGHAZ) is of particular concern because of its poor toughness. Work is continuing on the evaluation of CGHAZ toughness in commercial linepipe using the precracked instrumented impact test. Two commercial linepipe seam welds were evaluated in this way in the past year. In general the CGHAZ has a fracture initiation temperature about 40°C higher than that of the base metal, which can be mainly attributed to its coarse grain structure.

Although the development of HSLA steels for increased strengths and improved toughness has proceeded rapidly in the past 15 years, linepipe fittings have developed less rapidly thus they do not contain the same properties as the better linepipe steels. In particular, the weld metal of fittings is required to have a notch toughness of 40 J at -45°C at the yield stress required. Yield stresses greater than 415 MPa are difficult to obtain with present technology. A research program to investigate weld metal properties of fittings was initiated after discussions with fittings and welding-consumable manufacturers. A series of welds is being prepared with a range of wire/flux combinations using submerged arc welding and procedures typical of a fittings production shop. Initially the microstructure and mechanical properties of each consumable combination will be assessed in the normalized and stress-relieved condition.

Materials for Offshore Structures - CANMET metallurgists commenced research on the development of steels required for a variety of engineering structures for Canada's offshore energy reserves. This work is being funded under the National Energy Program. As these structures will be exposed to severe environmental conditions, the steels used must have properties superior to those of steels used in most engineering structures. A consultant experienced in the development of the North Sea hydrocarbon resources presented seminars at CANMET which assisted in defining material problems. Research scientists visited laboratories in Europe where much of the research has been carried out on materials for offshore structures. They also obtained essential information on corrosion fatigue by attending a conference on the results of the European Communities' five-year research program on steel in marine structures. Five year research contracts were initiated during the year, related to these projects. These contracts were for a review of steels used in offshore structures and regulations imposed by governments on steels and weldments used, with particular emphasis on the relationship between fracture properties and service temperature. A contract was awarded for a survey of the expected demand for steel plate for building offshore structures and arctic vessels, and to determine the ability of the Canadian steel industry to meet the demand. Other contracts were for research on corrosion fatigue of tubular joints and to characterize the fracture resistance of four grades of Canadian produced structural steel plate. Another contractor was asked to design a heavy-section impact fracture testing machine for use in building arctic icebreaking tankers and liquefied natural gas carriers as well as offshore structures.

CANMET laboratory research during this period consisted of a review of the finite element analysis programs and techniques used in the design of offshore structures and the development of finite element analysis techniques to describe the stress intensity at a growing fatigue crack at the weld toe in heavy plate specimens. A comprehensive fatigue and corrosion fatigue research project is being planned which may be extended to include testing of tubular joints. Other research areas included welding and weld treatment to enhance fatigue resistance, and non-destructive evaluation and study of steels having excellent low temperature properties. A contract for a research program on steels for offshore structures, co-funded by Energy, Mines and Resources, was formulated and advertised through the Department of Supply and Services. Companies in the steel industry were invited to submit proposals on steels for offshore structures.

Coal Technology

The lead agency for coal R & D in the federal government is EMR Canada. Canadian utilities and industry are converting from premium liquid fuels to indigenous, often low-grade coals, in response to federal initiatives to achieve oil independence and energy security under the National Energy Program. Increased expenditures on coal research have resulted in expanded program activities under the CANMET Minerals and Earth Sciences Research Program, Energy Technology Activity. These new coal technology activities focus on many aspects of coal mining, processing and utilization.

Coal Mining Technology - CANMET's Western Office in Calgary continued its program of assistance to and cooperation with coal mine operators to study and improve coal mining methods. The objective is to determine and foster adoption of the most appropriate mining technologies in Canada by conducting research in strata behaviour associated with mining methods applicable to the Canadian geological environment. As the modern coal industry in Western Canada has existed for only ten years, it mostly employs coal mining technology used elsewhere in the world and introduced here with varying degrees of success. As the success of these technology applications is largely dependent on a knowledge of the local geology and an appreciation of the strata response that is expected for a particular mining method, it is difficult to predict the behaviour of strata in many new coalfields and as a result the mining risk is high. Research is carried out where access to experimental sites is available and agreement between researchers and operators on pertinent questions can be obtained.

Studies are continuing on the effects of mining a thick inclined coal seam in mountains by hydromining. Subsidence over the active mining area is being monitored by tiltmeters, aerial photogrammetry, and a network of surface stations using a laser theodolite. An analysis has been made of the aerial photogrammetry data, and researchers have been gaining experience with the tiltmeter-ratio telemetry system.

A comparison will be made soon of available data on the three approaches to subsidence monitoring which will become an expanded activity in the future. An overview report is in preparation on strata mechanics work done in the past in the hydromine.

Because access was not available to the site, plans to develop a "punch" mine in the foothills were changed and instead it will be the location of an underground mine using a room-and-pillar system initially and possible longwall in the future. Also a methane desorption study was undertaken using samples from exploration drilling. A review of rock property testing for coal mining applications was prepared at the same time to justify establishment of a test facility. Future work at this site will include development of long-range research plan, testing of structural properties of rock formations in the area and development of rock classification system for coal mining. An evaluation of the applicability of bucketwheel excavators was completed, and an open seminar was held to assess the conclusions and identify the opportunities. Researchers developed a computer program to select technical features of bucketwheel excavators for specific applications, and cutting resistance tests were carried out on oil sand and coal specimens. This work was discontinued and it was decided to increase the emphasis on coal reserves work, especially surface mining technology.

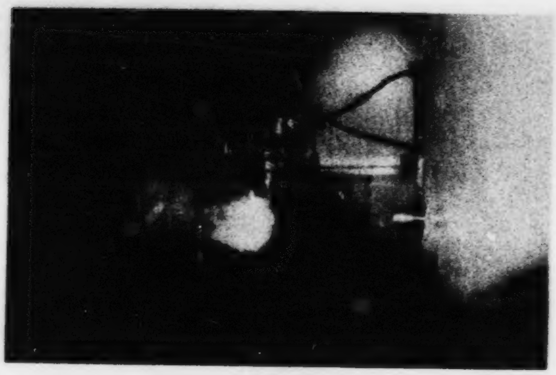
Staff of the Cape Breton Laboratory spent most of the period under review working towards the establishment of this facility. Also, researchers from this laboratory together with personnel from the Mining Research Laboratories in Ottawa conducted a brief field investigation which determined the level of ground vibration in the Prince Mine due to blasting in nearby strip mines.

Researcher G. Lobay (R) and technologist S. Ferguson operate control console of explosive atmospheres tests facility

Technologist S. Ferguson checks air velocity prior to performing spray ignition tests on hydraulic fluid used in mining equipment

Coal Mining Equipment Safety - CANMET's Canadian Explosive Atmospheres Laboratory continued its R & D on mining equipment safety as part of its function to certify equipment for safe use in coal mines. Its objective is to provide certification to industry on a cost recovery basis, of coal mining electrical and diesel-powered equipment, as safe for use in explosive underground environments. This service was supplemented by carrying out related equipment development, and by participation in standards-writing activities. This laboratory was established in 1953 and an Order-in-Council empowers the "Federal Certification Officer" to undertake the work of equipment certification. This original mandate has evolved slowly over the years to include numerous fire resistant materials and fluids, diesel machinery and explosive gas detection equipment in both underground and industrial hazardous locations. Other agencies such as Canadian Standards Association, Underwriters' Laboratories of Canada and Canadian Gas Association send such equipment to CANMET for specialized testing.

Laboratory staff conducted a training course for flameproof and intrinsically safe equipment attended by Alberta and British Columbia mine inspectors, representatives from McIntyre and B.C. Coal mines and from a diesel manufacturer's distributor. CANMET investigated two marine disasters at the request of the Canadian Coast Guard, determined the cause of each accident and submitted reports on the conclusions.



Demonstration test of the flammability of hydraulic fluid using spray ignition test apparatus

Researcher N. Sarin performs wick flammability test for hydraulic fluids used in mining equipment

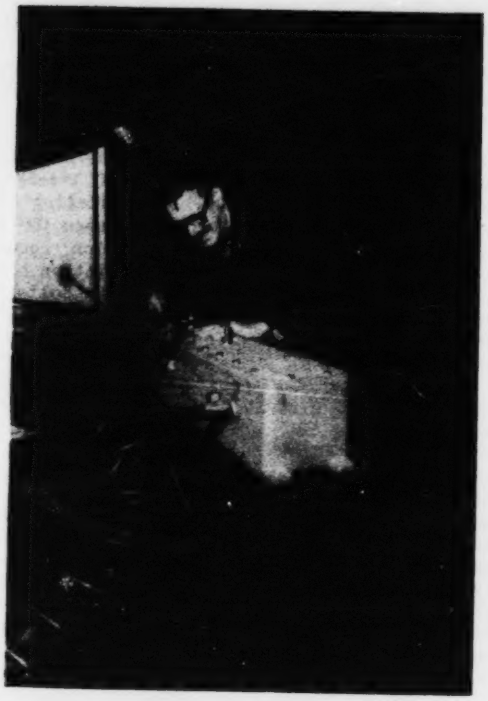
A new facility for full-scale testing of fire-resistance conveyor belts, which is the only permanent establishment of its kind in North America, was completed in 1981. CANMET provided technical assistance to the Beaver Company and their contractors for the flameproofing of several diesel machines to be used for driving the entrance tunnels for the new Donkin mine in Nova Scotia. The laboratory tested three designs of flame arrestors for use in gas compressor stations for the Alberta government. These arrestors, which were suspected of being responsible for several gas plant explosions in Alberta, were found to be deficient.

Underground Environment - CANMET's Western Office in Calgary has been researching methods for early detection of heating in coal seams caused by spontaneous combustion. By monitoring carbon monoxide generation or infrared detection the hazard of fire in underground mines can be reduced by early control action. Similarly, early detection of methane emissions from coal seams can effectively provide a first step in preventing severe explosions underground. A methane/airflow single point monitoring system (Siegar Ltd.) has been in operation for one year at a producing mine to study methods of reducing coal mine fire and explosion hazards. A contract was negotiated for a trial of the multi-point environmental monitoring system developed by Conspec Controls of Toronto. CANMET tested explosion proof materials for use in hazardous gas locations in coal mines to study ignition source control in order to identify design criteria for mine equipment used in Canadian industry. Several flameproof projects were carried out to provide design criteria for flameproof water-filled diesel exhaust cleaners which defined principles to minimize explosive pressures thus reducing the design pressure to lower values. Another project is continuing to determine the stress levels of relatively large areas of thinner flat steel plates which will withstand internal explosions and limit deformation to acceptable levels in protecting the workers' safety. A Canadian Standards Association subcommittee for the drafting of the Canadian code for underground diesel equipment was established in 1981 and a draft report describing acceptable equipment standards for all of Canada is being prepared to assist equipment manufacturers, mine users and regulatory agencies.

Contract research continued to develop an underground monitoring system to assess the levels of toxic constituents in the underground environment and to demonstrate the effectiveness of diesel emissions reduction strategies by underground trials of a dedicated reduced emissions prototype vehicle. Considerable progress was made in studying coal mine ventilation and energy systems for mine operation control, as well as systems for monitoring toxic materials in underground mines. Advances were made in the development of a second generation "mine atmosphere monitoring laboratory", and contract work was completed to determine the feasibility of establishing such a laboratory for the Canadian mining industry. Progress was made in promoting the Air Quality Index for evaluating the toxicity of underground environment where diesel equipment is used. CANMET designed an improved water scrubber for coal mine diesel emissions control, capable of removing 40% of exhaust-borne soot. This design was transferred to a Canadian equipment manufacturer resulting in considerable savings for Canadian mining contractors who now have a domestic source of supply for this mandatory emissions control device. A CANMET contract resulted in the design of water-conserving high performance Venturi-type diesel exhaust scrubber capable of removing up to 70% of the particulate matter from engine exhaust emissions. Research to promote the means of maintaining safety in underground coal mines involving potential methane/coal dust explosions resulted in a system to classify Canadian coal dust with respect to ex-

Researcher M. Ralph ignites propane burner for gallery testing conveyer belt

A Fire-resistant conveyer belt is tested in propane burner



Technologist S. Ferguson adjusts apparatus for an experiment on explosion testing

Technologist S. Ferguson prepares sample for explosion testing

plosibility index. Studies were carried out in cooperation with coal mining companies to determine the average methane content of coal samples from various depths. Estimations of the methane gas content of coal samples taken from one mine for methane desorption tests by the direct method indicated that the average methane content was 5.7 cc/g and the average gas content of coal seams in other mines was a function of depth.

Coal Preparation - The application of processes to upgrade coal mine product to improve utilization efficiency is defined as coal preparation. CANMET research involves developing methods to remove impurities such as sulphur, ash and other mineral matter, to adjust the water content, and to turn out consistently a product uniform in size and quality. Preparation can reduce environmental emissions and transportation costs besides eliminating some of the technical problems encountered in final consumption. These are important considerations for both the coal producer and user, especially with the present economic situation and current environmental control regulations. They were important factors in the development of export markets for Western metallurgical coals, and with the advent of strict sulphur emission regulations more thermal coal used in Canada may be required to undergo coal preparation hence thermal drying.

CANMET has been long involved with research activities in coal preparation and benefication, and many developments have been made by researchers in both the energy and mineral programs. One important innovation was CANMET's automedium cyclone used in the Western Research Laboratory in Edmonton for many projects carried out in cooperation with the coal industry in studying the characteristics and preparation requirements of commercial coals. Pilot-plant tests were run on coal samples provided by the mines, making it possible for researchers to study more completely the techniques best suited to their particular circumstances. Improvements in process development included installation of a 0.6 m diam model thickener in the 150 kg/h miniplant. After initial testing, the possibility of adapting the model to the high capacity thickener design as an additional option was studied and plans were underway to add monitors and controls for computer interfacing.

The addition of the Batac jig to the 10-t/h pilot plant was completed with financial support of the coal industry and this increased its capability to assess the application of this unit to a wide range of thermal, metallurgical and highly friable coals. Start-up problems related to the float control were resolved early in 1981 by addition of a ring-type system, and a bottom-feed thickener necessary to ensure a clean water supply for the jig was received at year end. These equipment changes were made so that most effective use of metallurgical and thermal coal resources will be ensured by the development and application of the most appropriate and economical processing methods.

Research continued on the application of processes to beneficiate fine oxidized coals from Western Canada. Continued financial support was received from a large resource company in a five-year study involving development of methodology and instrumentation for the characterization of oxidized coals, micro-flotation testing and scale-up to bench- and possibly pilot-plant scales. Contract research completed during the period on feasibility of two surface characterizing techniques indicated that Fourier Transform Infra Red (FTIR) showed the greatest promise for studying oxidized coal. Development of a promising method for contract angle measurement of fine particles continued under a research contract at the University of Toronto. Instrumentation was acquired and preparations were underway late in 1981 to apply Raman spectroscopy to the study.

Results of studies of the major operating variables and interactions and their effects on recoveries and coal products indicated that the optimum solution to improved recovery efficiencies of fine coal at preparation plants will come about through the use of various combinations of processes now available at these coal operation establishments. The availability of washing processes such as the heavy medium cyclone, hydrocyclone, jig and flotation in CANMET's pilot plant in Edmonton now makes it possible to test numerous flowsheet options to arrive at an optimum equipment combination for a particular fine coal. This capability, which is unique in Canada, is essential to assist in the design of new washeries and in trouble-shooting for existing fine coal operations. The use of computer models for simulation of separation processes at Canadian wash plants is invaluable for plant design, flowsheet optimization and feasibility studies. Models developed at the Western Research Laboratory in 1981 using partition curve data from various sources were tested and found applicable to Canadian coals.

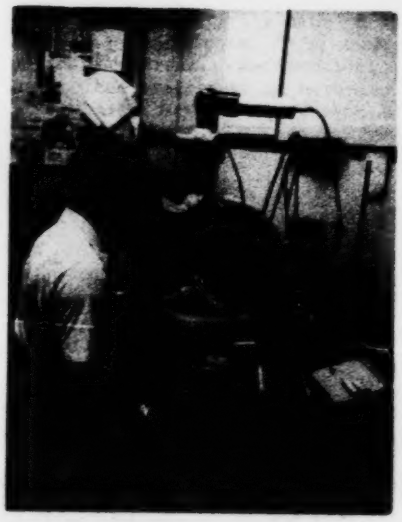
A contractor conducting water treatment R & D completed work on characterization of commercial flocculants. The possibility of predicting behaviour and optimizing separation processes for very fine particulates in water suspension requires knowledge acquired through characterization of the particulates and flocculants and their collective environments as well as knowledge of the mechanisms of flocculant action. This contractor verified on the basis of correlation with viscosity, the laser-scattering technique for determining molecular weight distribution in the 10-15 million range for a few non-ionic and anionic polymers. A screen-flow technique for measuring the degree of polymer degradation was developed under contract at the University of Toronto. Both techniques will be valuable for determining flocculant characteristics and effective parameters for water treatment and other polymer applications, especially in enhanced oil recovery. Improvements in software and interfacing for the prototype 8-cylinder automatic settling rate apparatus made it possible to perform numerous settling tests on a set of three coal washery effluents for evaluating performance of a number of polymers as settling and filtration aids. All of the reagents gave substantial improvements for both applications, but results indicated that the best reagent for one application could be the worst for another. Numerous tests were also performed on a troublesome washery thickener feed for screening reagents in preparation for mobile plant field tests. The results yielded a number of potentially good flocculant combinations and indicated that the order of addition of cationic and anionic flocculants was critical for achieving adequate settling and clarification.

Modifications including the installation of various additional controls and monitors were completed in 1982 to CANMET's mobile water treatment plant. Since time was insufficient for completing preliminary laboratory work, no additional field testing was done.

Carbonization - Exports of coking coals were an important part of Canada's external trade in 1981. Total coal exports amounted to 16.2 Mt, of which 14 Mt was metallurgical coal intended for the steel industries of the Pacific Rim market. Considering the recent development of several new mines in British Columbia, Canada's metallurgical coal exports are expected to be about 25 Mt by 1987. The Canadian steel industry consumed approximately 10 Mt of metallurgical coal in 1981, most of which was imported from the U.S. The importance of this trade situation emphasizes the relevance of CANMET's R & D program designed to improve the quality of coke made from blends of Canadian and imported coals, to encourage the use of Canadian coals in Canada and to ensure that coal exports are competitive. The objectives of carbonization R & D projects are to improve the predictive and characterization techniques that can be used in assessing coal potential in cokemaking, and to demonstrate on a technical scale, new technologies to improve the quality of coke that is produced by Canadian industry or that can be made from Canadian coals. It is also intended to support by research, development, demonstration and quality testing all coal and cokemaking activities of the Canadian iron, steel and coal industries.

CANMET laboratory methods based on chemical and petrographic analyses are used to predict the suitability of a coal resource for cokemaking. Tests are performed on promising coal samples in one of CANMET's four technical-scale slot type coke ovens - two at Ottawa and two at Edmonton - to make a satisfactory evaluation of the coking coal. These ovens have similar widths to industrial ovens and are used by companies in the Canadian coal and steel industries as well as CANMET scientists for research. A data acquisition system using an HP-85 microcomputer was installed in 1981 in Ottawa on the 460- and 310-mm wide ovens, a 15-kg oven and the sole heated oven to facilitate data handling, calculations, plotting of graphs, and reporting of results. Plans were made to install a similar system on the two moveable wall ovens in Edmonton.

Both the coal and steel industries must know how coke quality differs in technical-scale ovens from that produced commercially. The third in a series of four correlation studies between CANMET's technical-scale ovens and those of industry has been completed. Results from this study showed that each of CANMET's ovens produces coke having slightly different properties. For example, all ovens produce cokes having strengths similar to those of industrial cokes but variations occur for hardness and reactivity. On completion of the fourth correlation study, CANMET will evaluate the results to determine if any changes should be made to the ovens' operating conditions. Computer modelling of the carbonization process has produced temperature-time programs for use in the



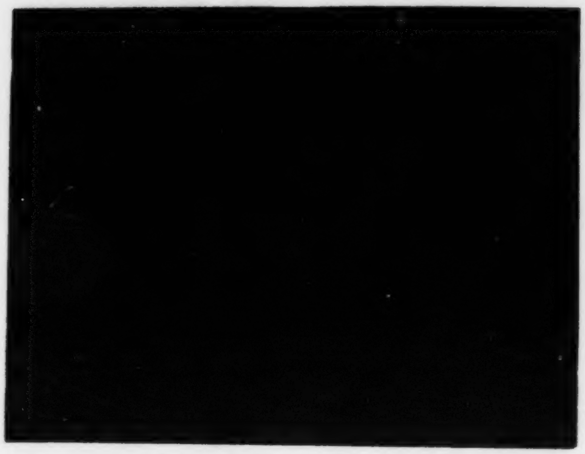
N. Ramey, technologist, uses Carl Zeiss OlK reflecting light microscope to determine textural structures in metallurgical cokes (R) for relating microsopic structures to coke quality ovens so they simulate more closely the industrial process.

CANMET continued investigations on partial briquetting of coke oven charges and determined that this technology, used extensively in Japan to reduce dependence on imported coking coals, can improve coke quality for coal blends used by the Canadian steel industry. Recent technical-scale oven tests using four heating rates showed that industrial coke oven productivity could be increased by 25% by using partially briquetted charges and a faster coking rate, before coke quality deteriorated. Previous CANMET investigations in pilot-scale coke ovens on the use of additives for improved coke quality showed that coke quality could be enhanced by adding pitch materials to poor-coking high-inert coals. However, these improvements had not been sufficient to produce coke of metallurgical quality. The results of current research using CANMET's 310-mm pilot oven indicated that excellent metallurgical coke can be produced from a marginal Western Canadian coking coal by adding 10% of an experimental pitch made by CANMET. These results give credibility to earlier small-scale canister investigations which predicted that coke quality could be improved through the addition of certain pitch materials to coke oven charges.

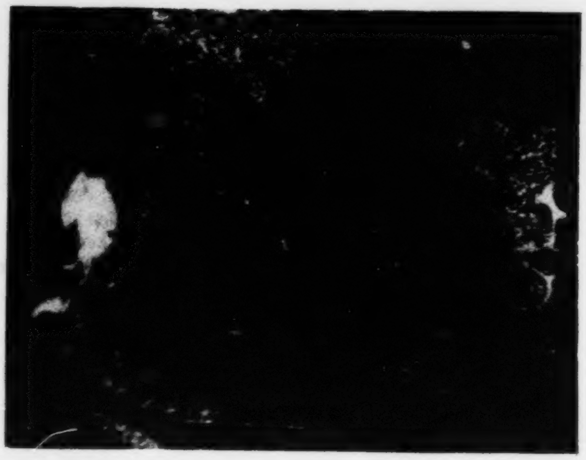
A major item in the Coal and Coke Constitution Section research productivity on basic coal research deals with the upgrading of inert-rich oxidized coals from Western Canada using reducing gases. It was demonstrated that treatment of these coals with carbon monoxide and water under specific conditions of temperature and pressure yielded coals with improved reactivity properties for process utilization. This research is being actively pursued and was the subject of three conference presentations during 1981-82.

Pressures exceeding 14 kPa exerted on coke oven walls during coal carbonization are considered dangerous and can cause damage to coke oven batteries. Wall pressures are routinely monitored during technical-scale testing but have been found to vary for each depending on its operating conditions. CANMET is attempting to relate maximum coke oven wall pressures to coal bulk density and coking rates by cross-monitoring internal gas pressures. Internal gas pressures in industrial coke ovens will be measured and related to those of CANMET's ovens under contract to Algoma Steel Corporation in 1981.

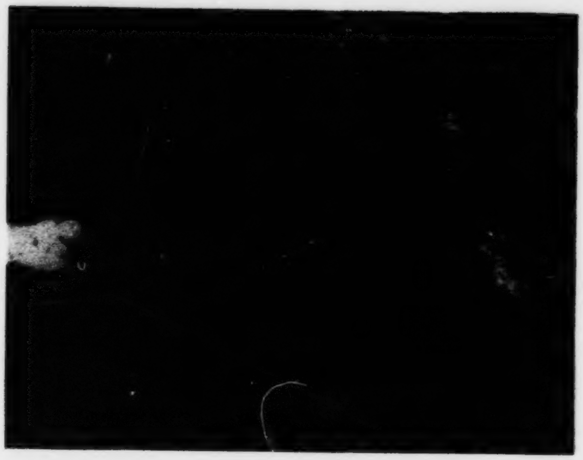
Coke quality can generally be determined by tumbler tests at ambient conditions, but ultimately its strength and resistance to abrasion is evaluated by its performance at high temperatures in the blast furnace. CANMET research during 1981 included assessing the strength of cokes after reaction with CO_2 at 1100°C in conjunction with partial briquetting and pitch additives programs in an attempt to determine better the behaviour of coke in the blast furnace. Partial briquetting of an industrial coking blend was found to decrease the reactivity of 20-mm coke and increase its strength after reaction with CO_2, when compared with conventional coke. When the cokes were pulverized to minus 850 plus 350 µm however, no difference in micro-reactivities was found between cokes from conventional and partially briquetted charges. Cokes made from charges containing special pitch additives or charges carbonized at higher flue temperatures also had better high-temperature properties. These coke properties were studied by new methods based on microscopic analysis. Microscopic point counts of cokes made from the addition of different pitch materials to a low-volatile coal has shown that these pitch additives can modify the relative amounts of isotropic and various anisotropic textures in coke. This



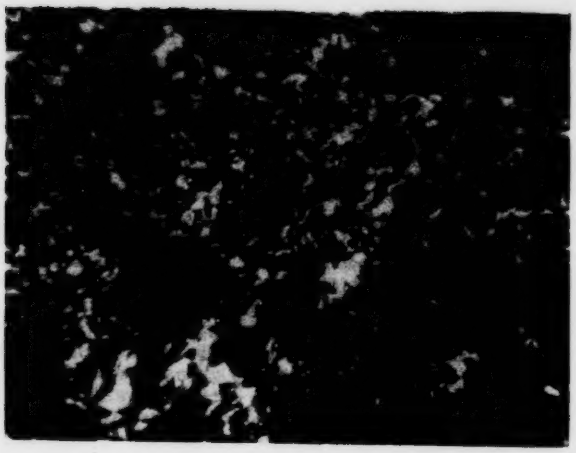
(a) Semi-coke of naturally oxidized Eastern Canadian coal. No evidence of coke formation due to oxidation



(b) Semi-coke of same coal treated with CO in the 350 - 450°C and 6.9 - 13.8 MPa range. Evidence of formation of coke structure



(c) Semi-coke from naturally oxidized Western Canadian coal shows slight formation of coke structure



(d) Semi-coke of same Wester Canadian coal treated with CO and H_2O (water-gas shift reaction) in the 350 - 450°C and 6.9 - 13.8 MPa range. Evidence of extensive flow-type coke formation

analytical method also produced results which showed that the percentage of reactive semi-fusinite can vary considerably for different Western Canadian coals.

Coal Gasification - The objective of the program on coal gasification, the reaction of coal with oxygen and steam, is to develop information on the gasification characteristics of various Canadian coals. CANMET's in-house research is directed towards understanding gasification mechanisms and compiling chemical reactivity data on those Canadian coals which could possibly be used in various gasification processes. The chemical reactivity data are for the assessment of advanced gasification technologies for the conversion of coal to gas, electricity, methanol or chemicals in various regions of Canada using local feedstocks. Researchers are exploring the potential for extracting valuable liquids from coal, pitch and oil shale by processes combining pyrolysis and gasification.

Achievements of outside contract research during the first six years of the program included the spouted-bed technology developed at the University of British Columbia for gasification of Western Canadian caking coals. This technology will be tested further at bench scale and possibly at pilot scale with a coal capacity of 12 t/d. New processes for cleaning up hot producer gas are being developed to minimize environmental pollution and attain maximum efficiency of the combined cycle power generation via the gasification route.

CANMET began research on pyrolysis (devolatilization) of coal as a first step in providing an alternate route for the production of valuable liquids, before the char gasification step in the process. Preliminary pyrolysis experiments proved it possible to skim off the liquids from coal before gasification, which showed that pyrolysis reactions can be applied to materials other than coal, especially pitch and oil shale. Some preliminary work was started to determine the suitability of these materials as feedstock for liquid production. A rapid method is now being developed for characterization of coal and oil pitch using the finger printing technique of pyrolysis-GC.

Recent work established a relationship between the chemical reactivity of nine Canadian coals and their rank under two gasification conditions, and determined that generally the reactivity of coal increases with decreasing rank. Studies showed that each coal has its own gasification characteristics with different products and chemical reactivity.

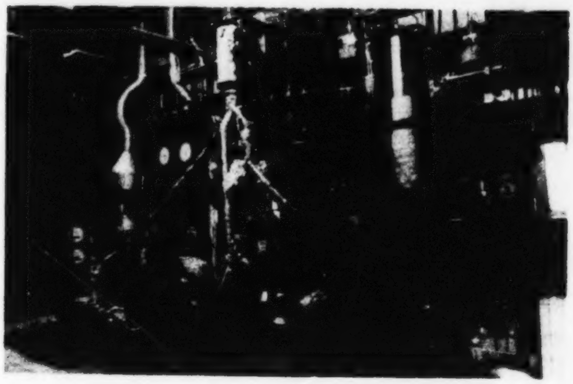
Pitch derived from hydrocracked Athabasca bitumen could be a source of liquid hydrocarbon when pyrolysed prior to gasification. Mathematical simulation of pitch pyrolysis in a moving bed type of riser reactor indicated that the mass ratio of solids to feedstock would have to be greater than 10, and temperature of circulating solids supplying heat for pyrolysis reaction should be higher than 800°C. Preliminary kinetic data indicated that about 20% of pitch would be converted to liquid hydrocarbons by pyrolysis either with or without Al_2O_3 catalyst, but noncatalysed pyrolysis would require a reactor about three times the length. This study also showed there is a possibility of using carbon dioxide and steam as a carrier gas for lifting solid material throughout the reactor.

Coal Liquefaction - Coal liquefaction technology better suited to the coal resources and market demands of the country can be obtained by promoting its development in Canada. This could reduce Canada's dependence on imported technology, help train more Canadians and should lead to a technology export market. The CANMET coal liquefaction program is addressing these issues through an in-house research program and a contract program with national participation.

In the in-house research and development program three interrelated experimental projects are being carried out. The first project is concerned with the design, construction and operation of a continuous-flow coal liquefaction unit. This unit was commissioned in 1981 and is being used to characterize the reaction behaviour of different coals using bitumen and heavy oils as liquefaction solvents. Preliminary results using a subbituminous coal and a heavy oil vacuum residue from Alberta have been encouraging. In the second project a bench-scale continuous-flow by hydrogenation unit is being constructed under contract to CANMET. This unit will be used to prepare special liquefaction solvents and can also be operated to study the upgrading of coal derived liquids. This art is not expected to be operational until 1983. The objective of the third project is the development of small-scale batch and micro-continuous facilities to investigate different aspects of the chemistry of coal and solvent interactions. Designs for both systems were completed early in 1982. Commissioning is not expected until early 1983. As part of this project, laboratory facilities in the coal liquefaction section have been expanded. The laboratory is now equipped with both analytical and preparative high pressure liquid chromatography which will be used for isolation and characterization of coal derived liquid products.

Technologist J. Whitten works on pressure vessel system of continuous flow coal liquefaction unit

Technologist J. Whitten operates continuous flow coal liquefaction unit



View of the recently commissioned continuous flow coal liquefaction unit

The coal liquefaction contract program, while in its sixth year, received a significant increase in funding in 1982. This increase was partly due to changes in the National Energy Program and as a result of the increased awareness in the private sector of the longer term role that coal liquefaction can play in meeting the future energy requirements of the country. The overall program is divided between a shared-cost program with interested industrial participants and a fully-funded program directed towards research projects of specific interest. The overall objective of the shared-cost program is to contribute to the definition, research, development and demonstration of different coal liquefaction technologies by sharing costs with appropriate private sector partners. Normally, federal government participation is limited to a maximum of 50% of the total cost of each project. Most of the emphasis to date has been on Western Canadian coals although a project in Nova Scotia has been funded since the start of the program. The main objectives of the fully funded program are to develop Canadian interest and expertise in coal liquefaction and to generate a national data base on the liquefaction behaviour of different Canadian coals. The principal priority areas for the program are the co-processing of coal with bitumen or heavy oil, flash hydropyrolysis, pyrolysis and supercritical gas extraction of low-rank coals.

Conventional Coal Combustion - Activities are directed toward the development of new or improved techniques for efficiently utilizing pulverized coal and renewable fuels as a substitute for oil in industrial processes. Canadian utilities and private companies are quickly converting from premium liquid fuels to indigenous, often low-grade coals, in response to federal initiatives to achieve oil independence and energy security under the National Energy Program. Canadian coal companies are also trying to capture a reasonable share of the world market, often with newly developed thermal coals of unknown quality and performance. These activities have resulted in a collaborative government/industry combustion research program, under the CANMET Minerals and Earth Sciences Research Program. Researchers are concentrating on defining and optimizing the combustion performance of low-grade coals from new mines or waste materials in pulverized-fired combustion systems, and promoting the use of coal-liquid mixtures as a substitute fuel for oil in existing oil-fired equipment as well as an alternative to direct coal firing in other combustion equipment. This work involves projects to conserve and improve the use of fuel oil through operational and design modifications to industrial combustion systems, as well as to minimize the environmental effects of the increased use of coal.

Combustion research scientists conducted tests on coals of different ranks to characterize the flame and heat transfer properties of raw, beneficiated and blended thermal coals, as well as washery rejects for use as substitute fuels in industrial process kilns currently fired with oil or gas. These tests conducted in CANMET's pilot-scale tunnel furnace and research boiler were done in collaboration with or on behalf of coal companies or utilities. The variables studied included ignition, flame stability, emissions, combustion stability, burn-out, slagging and fouling. One objective of this work is to optimize conditions to achieve the best combustion performance.

CANMET is studying the expanded use of low grade coal in electrical utility boilers. The overall objectives of this project are to evaluate the combustion slagging and fouling properties of coals from newly opened deposits for use in power utility boilers, and to minimize emissions from conventional coal combustion through control of flame properties, chemical additives, burner design, flue gas clean up and atmospheric dispersion. Combustion researchers conducted a series of tests in collaboration with Suncor Inc. to determine the effectiveness of firing limestone additions at various levels with pulverized petroleum coke to reduce sulphur dioxide emissions. Results showed that limestone additions did not affect nitrogen oxide emissions. CANMET also undertook a project in collaboration with Allied Chemical Canada Ltd. to study the addition of calcium carbonate and calcium chloride to the blended coal used at the Nanticoke Generating Station of Ontario Hydro. The combustion of this coal blended from Pennsylvanian and Western Canadian thermal coals had previously been studied in the pilot-scale boiler at the Combustion Research Laboratory. The combustion tests with various combined rates of additions of calcium based chemicals were completed, the data were analyzed and a report is being written on the results.

Plume Dispersion - In 1981, consolidation of the plume spread data generated during six years of research in the CANMET/industry plume dispersion program, resulted in a paper presented at the 74th annual Air Pollution Control Association meeting in Philadelphia.

The plume spread parameters have been evaluated and compared with the standard predictive relationships established by Pasquill and Gifford. The data corresponds to neutral and stable conditions but excludes any limited-mixing or layered atmosphere studies or situations where topography influences plume spread. In all, ten sources in five geographic regions were studied during spring, fall and winter. It has been shown that the Pasquill-Gifford curves as modified by Bowne for rural conditions represent a convenient means of comparing the data obtained under corresponding stability and topographic conditions in Canada. It was also found that the bulk Richardson number could be used to classify the plume spread parameters in a similar manner to the Pasquill-Gifford stability classes. The consolidated data reported in the above paper have been accepted for publication in Atmospheric Environment.

Combustion of Coal-Liquid Mixture (CLM) Fuels - Increased oil prices and instability of offshore supply to Eastern Canada, combined with abundance of domestic coal supplies has led to a research and development program including technologies relating to the production and combustion of coal-liquid mixture fuels. These technologies have significant potential in reducing oil consumption at power stations, and in industrial steam raising and other process equipment originally designed for oil-firing and not readily convertible to alternate fuels. The department is supporting the utilization of CLM technology in Eastern Canada through its National Energy Program's special Atlantic initiatives. Phase III of a demonstration-scale project being carried out by CANMET and the New Brunswick Electric Power Commission in the 10 MW(e) No. 1 utility boiler at Chatham, New

Brunswick has the objectives of testing the application of the spherical agglomeration process to the beneficiation of high-ash Eastern Canadian coals and its integration into CLM preparation, and examining two types of burners constructed of several different materials to minimize the erosive wear of burner tips. Burner design and materials selection are important considerations in the development of burner components which will satisfy commercial performance standards. Equipment damage was caused by the highly abrasive slurry but this problem can be eliminated by appropriate materials and design considerations. Pipework was relatively unaffected by wear essentially due to the low prevailing fluid velocities. The major problems of burner tip erosion may be solved by choosing a less abrasive coal, improved coal cleaning by ash and pyrites reduction, further reductions in coal particle size, burner tip materials selection, and the use of externally atomizing burners using low CLM efflux velocities.

CANMET and the Ontario Research Foundation are jointly studying the erosive behaviour of burner tips during combustion of coal-liquid mixtures made from Eastern Canadian coal. The major problem in gaining acceptance of coal-liquid mixture fuels by industry in the Maritimes is the abrasiveness of the coals causing premature and unacceptable failure of nozzle components. Two combustion tests were carried out in a small 10 GJ/h boiler in which a Y jet internal-mix burner of typical design was compared with a highly turbulent external-mix burner. Both burners were steam atomized and had been tested in previous CLM evaluations. Erosion rates were decreased by more than half in the external-mix burner when compared with the Y jet burner. An initial period of accelerated wear for both burners occurred within the first few hours due to a "breaking-in" of the nozzles from the polishing action of the coal and ash particles in the fuel.

General Comminution Incorporated completed a joint project with CANMET to develop operating data and scale-up information on a small Szego orbital grinding mill having a coal capacity of 1 to 3 t/h. This mill offers attractive advantages in size, power requirements and its ability to grind coal in liquids to very fine sizes having a mean diam of 15 μm. Scotia Liquicoal is conducting a research study on coal-oil emulsion preparation using feed coal milled to about 15 μm mean diam in the Szego orbital grinding mill and then beneficiated using the National Research Council's spherical agglomeration process. This coal-oil emulsion preparation facility incorporates these two developing Canadian technologies in a small pilot-scale plant having a fuel capacity of 6 t/h. This combination should provide much information on the commercial feasibility of the mill. This research project to find viable alternatives to fuel oil in Nova Scotia was funded by the Canada-Nova Scotia Oil Import Substitution agreements administered jointly by Canada and Nova Scotia. CANMET and the National Research Council's Atlantic Research Laboratories are presently providing funds to develop a burner which will resist the abrasiveness of the fuel and withstand a 1000-h combustion trial in a 20 GJ/h industrial boiler.

CANMET is collaborating with the Centre for Energy Studies, Technical University of Nova Scotia in a project to survey and evaluate commercially available oil-burning equipment and to assess its potential for CLM combustion in a specially constructed test facility in Nova Scotia. Major oil burner suppliers in both the utility and industrial fields, as well as manufacturers experienced in systems for handling CLM supplied information. The final phase of the project was a review of testing methods for oil burner nozzles for use with CLM fuels and preparation of a report, which is now available.

The Atlantic Coal-Liquid Mixtures Group is a coordinating body for CLM technology developments in the Maritimes, which was formed in early 1981 to review research proposals before submission to the various funding agencies. Informal information exchanges at early meetings were followed by a successful workshop on CLM technology which the group held in December 1981 in Halifax. Interested participants from the Maritime utilities, coal producers, private industry, universities and other research agencies as well as CANMET and the coal branch of the departmental energy policy sector comprise the working group. This group provides input to the technical committee of the CLM-project being undertaken by EMR in the Maritimes.

The International Energy Agency Coal-Oil Mixtures Implementing Agreement is a cooperative agreement in which the participating countries agree to technical cooperation and exchange in various specific areas of CLM-technology development. CANMET represents Canada which signed the agreement together with Sweden, Spain, Holland, Japan, U.S.A. and the U.K. Annex 1 of the agreement is an assessment within each participating country of the potential for CLM conversions, fuel resources and of support research and development activities. Other annexes dealing with utility and industrial CLM demonstration, research and development base technology support, and coal beneficiation/CLM preparation, are being developed.

Fluidized Bed Combustion (FBC) - The benefits to Canada of the application of FBC technology are potentially great because of the following:

- The ability to burn high-sulphur coal such as those in Eastern Canada with convenient control of SO_2 emissions by means of limestone injections.

- The ability to burn fuels having combinations of high moisture content, high ash content and low reactivity, such as wood waste, coal washery rejects, and coke byproducts of oil sands extraction.

- A solid fuel-burning technology which is economic in small as well as large installations, and thus might provide a means for utilizing coal or wood waste to replace oil and natural gas in the commercial and industrial markets.

- A potential means to achieve more efficient coal-to-electricity cycles, through combined cycles based on pressurized fluidized bed.

The CANMET energy program continued giving very high priority to encouraging the rapid application of FBC technology to meet Canadian needs through pilot-scale R & D and the support of full-scale demonstration projects. Increased funds were allotted to support its development in 1981 in accordance with the National Energy Program. The application of this technology to coal-fired steam generation is still under development and only a few commercial-scale demonstrations are in operation. Designers of full-scale FBC equipment have a continuing requirement for detailed information. Accordingly, in 1975, CANMET began to develop pilot-scale facilities to create performance data for various Canadian fuels and sulphur sorbents.

A demonstration project co-sponsored by EMR and Department of National Defence (DND) involving the installation of atmospheric FBC boilers in a heating plant addition at CFB Summerside, P.E.I. has been completed. The design fuels were Cape Breton coal containing 5% sulphur, co-fired with wood chips providing up to 30% of total heat input. A detailed design and firm price proposal was completed in early 1981 when two companies submitted tenders for construction of the plant addition. This turnkey plant contains two FBC boilers rated at 18 000 kg/h each, fuel storage and handling equipment, and other auxiliaries. Foster Wheeler Ltd. was awarded the contract in February 1981, construction of the plant was carried out on schedule and the addition is expected to be commissioned in December 1982. CANMET will be the lead agency in evaluating the performance of this demonstration project costing $13.1 million. DND was concerned at the cost of limestone required as a sulphur sorbent, which is available from New Brunswick from $5.50 to $20.50/t. In response, CANMET initiated a research project in which all three sizes of limestone will be tested with the design coal in the Mark II pilot-scale FBC combustor to determine which size performs satisfactorily.

CANMET continued as technical adviser on a proposed project to demonstrate an atmospheric FBC boiler in Nova Scotia Power Commission's Point Tupper plant, for generating electricity from high-sulphur coal. The proposal involves installing a 150-MW(e) FBC boiler to replace an existing oil-fired boiler to deliver steam to existing turbogenerator equipment. The project is funded under the Oil Substitution Agreement. The main technological obstacle expected is the potential for high-temperature corrosion of superheater tubes immersed in the fluidized bed. A 10 000-h program of pilot-scale metallurgical testing is being sponsored, to more reliably identify the most corrosion-resistant alloys, and thus reduce the risk factor. As no similar corrosion tests have ever been carried out, it was decided in December 1981 to engage Combustion Engineering Superheater Ltd. to design and build a 1-m^2 pilot-scale FBC unit at Point Tupper, where Nova Scotia Power Commission will run the test program. CANMET will provide advice on the design of the test combustor and will carry out the metallurgical evaluation. Corrosion experts from the U.S. and the U.K. are participating in the planning of the research program. This project will provide valuable information and considerable expertise to Canadian industry.

A contract-study was carried out and a report was completed by a Finnish company, A. Ahlstrom Ltd., to investigate the feasibility of burning high-sulphur coke from the Syncrude oil sands plant in a recirculating FBC. Twenty tons of Syncrude coke was burned in Ahlstrom's pilot-scale combustor using Swedish limestone as the sulphur absorbant, as no suitable limestone was available from the Ft. McMurray area. Test results were encouraging with combustion efficiency ranging from 95 to 98% and sulphur recovery of 90% was achieved with a Ca/S molar ratio of about 2. The contractor's report was released in December 1981 to the companies in the oil sands industry, for discussion and to reach a consensus on future action.

Another contractor completed testing on the coal applications of a proprietary feeder developed in Canada to feed hardwood chips into a high-pressure steam cooker. CANMET contracted for a series of bench-scale tests in which coal plugs were formed under various pressures, moisture contents and sizes. Their permeability to gas was measured at various pressures at McGill University under a sub-contract from Warnock Hersey Services Ltd. The results received in the final report in June 1981 showed that plugs formed at pressures from 3500 to 14 000 kPa can be impermeable at gas pressures up to 1400 kPa, and the pressure required to form an impermeable plug decreased as moisture content increased. This device appears to have potential as an improved method for feeding coal into pressurized reactors such as gasifiers and fluidized bed combustors.

CANMET co-funded a research project at Luscar Ltd. for engineering design and economic analysis of a FBC to burn coal washery rejects to provide plant heating and hot gas for coal drying. Dorn-Oliver Canada Ltd. provided the process design and Luscar Ltd. designed the building and materials handling facilities and carried out the economic analysis. This study, completed in 1981, indicated the total estimated cost for a system with a 250 million Btu/h input would be about $22 million. This proposal would be uneconomic under Luscar's company current investment guidelines, unless the federal government provided a subsidy of $8 million. The economics of drying coal using washery rejects as fuel depends on the types of fuels used in coal-dryer equipment and location of the coal plants. CANMET contracted a consultant to prepare a conference-type paper from the Luscar report to disseminate the results to other coal producers interested in the concept.

CANMET completed the installation of the new 38 cm x 40 cm pilot-scale Mark II fluidized bed combustor in 1980, to replace the 25-cm diam combustor operated from 1978 until mid-1980, for testing various Canadian fuels and sulphur sorbents. A contract was awarded to equip Queen's University with an identical facility. The construction was completed in 1981 and the contract was extended to include a program to evaluate the performance of various Canadian limestones as sulphur sorbents, and to clarify factors affecting efficiency

D. Desai, engineer, examines data from fluidized-bed combustion tests using Canadian coal

of sorbent utilization. The objective is to add to the database on FBC performance of Canadian fuels and sorbents. CANMET continued to represent Canada in a nine-nation information exchange agreement on atmospheric FBC, sponsored by the International Energy Agnecy.

Transportation of Coal Slurries - Capital investments of approximately $17.8 billion will be required in the next decade for the expansion of Canadian railway systems. Some major railway construction will be necessary to provide transportation for new coal mines being developed in remote areas. Coal slurry transportation could be an important alternative method for moving both domestic supplies and exports. CANMET undertook a comprehensive study to evaluate the potential of coal slurry pipelines in Canada based on regional availability of coal, water and crude oil. This study indicates that Western Canadian coal from 10 locations in northern Alberta and eastern British Columbia could possibly be transported in pipelines of the Black-Mesa type coal-water or coal-methanol slurry to West Coast ports. The coal-oil slurry could be an additional alternative for delivery to Eastern Canada. Pipeline transportation of coal could be cheaper than combined rail-Great Lake waterway transportation.

Two research contracts awarded by CANMET for experimental studies on the recovery of oil from coal-oil slurries by a two-step process were almost completed. These contracts were for research on three types of slurries prepared from two Canadian thermal coals, one metallurgical coal and commercial synthetic crude oil. A method based on centrifugal separation is being studied by the Saskatchewan Research Council. A continuous fluidized bed apparatus with a coal capacity of 15 kg/h was designed and constructed at CANMET's Energy Research Laboratories for use by Intercontinental Engineering Ltd. and B.C. Research in Vancouver for studies on coal-oil evaporation.

Materials Requirements for Coal Technologies - CANMET metallurgists are working towards developing materials that are resistant to abrasion and corrosion in coal conversion and utilization processes. Studies were completed on wear resistance of commercial alloys, various types of mild steel, carbon steel, stainless steel and titanium alloys in projects using aerated and deaerated coal slurries as a function of environmental variables such as slurry concentration, oxygen concentration, acidity and velocity. They developed an electrochemical technique that led to a method of determining erosion and corrosion. The erosion of carbon steel is small at low and intermediate velocities, and can be significantly reduced by a corrosion control method. The wear of carbon steel at 3 m/s was reduced by 95% with cathodic protection. Wear of Type 304 stainless steel was directly proportional to coal concentration up to 10% and remained constant above this.

Performance of various types of stainless steel boiler materials was studied under simulated FBC environments. The corrosion kinetics of the alloys in a synthesized flue gas containing high sulphur and low oxygen were followed at 900°C, and

CANMET's Mark II rig pilot-scale atmospheric fluidized-bed combustor used to study combustion performance of coals and other solid fuels, heat transfer rates in fluidized bed and to characterize limestone and sorbent additives for sulphur capture the morphology of the scale deposit was studied to determine the significance of sulphidation attack. The alloys were also exposed to synthesized coal ash deposit in the presence of the flue gas to simulate the corrosion of materials in the FBC. Results have shown that materials degradation was more severe through in-bed corrosion than by flue-gas corrosion.

A contract for high-temperature materials research to study corrosion and erosion of FBC boiler tubes was completed and the final report was released in 1982. This study was made to evaluate performance of ferritic and austenitic steel boiler tubes in an atmospheric FBC using high-sulphur coal. Another contract resulted in the development of a plasma vapour deposition protective coating for components of fossil energy conversion systems. Research is continuing. A third contract was awarded for the design and construction of a high-temperature erosion test facility containing equipment for studying behaviour of materials under high-temperature corrosive-erosive conditions. The design phase was completed and construction will start in 1982-83.

Coal Analysis - Canada's complex energy problems have stimulated interest in processes involving the utilization and conversion of conventional and alternative fuels. Successful refinement and development of the related techniques rely upon component analyses to assess the value of a particular research experiment or pilot-scale project. CANMET improved its analytical facilities to support its coal research and assisted in developing high levels of analytical expertise in other Canadian laboratories by expanding participation in the Canadian Inter-laboratory Coal Analysis Exchange Program.

Fifty-one laboratories, including thirty-nine in the private and twelve in the public sector now participate in the program. These participants have varying interests as some are purely scientific research organizations and others are strictly commercial coal operators. CANMET staff prepare and distribute approximately nine samples per year for analyses. These samples are obtained from various coal deposits and are representative of all ranks of domestic coal. The laboratories perform routine analytical determinations (proximate analysis, sulphur content, calorific value and free swelling index) on successive days according to ASTM standards and send the data to CANMET for statistical analysis. CANMET uses the data from all the laboratories to generate a computerized statistical analysis and a comparison of the calculated confidence limits of the analyses with the accepted limits published in current ASTM standards. This service for coal analysis is unique in Canada.

Nuclear Energy Technology

CANMET has been active in assessing Canada's nuclear fuel resources since the early days of this country's nuclear program. The branch joins other sectors of the department in determining national resources and reserves of uranium. Work on uranium mining and tailings disposal is described in the following section describing the Minerals Research Program. The description below outlines the work to improve the recovery of uranium and byproducts from ores, while protecting the environment.

Uranium Extraction - Current research at CANMET on uranium extraction involves the use of both conventional and new alternative process technologies. Conventional technology involves studies on preconcentration of uranium ores from the Elliot Lake area in Ontario before sulphuric acid leaching and comparing the results with those of conventional direct leaching. Optimization of the solid/liquid separation in various parts of the process is required to make the preconcentration more attractive. The general objectives of research on existing technology are to maximize the recovery of uranium from low-grade and complex ores, recovering all valuable byproducts such as thorium and rare earths and providing process technology with minimum environmental impact, especially isolating radionuclides allowing safe disposal of tailings.

CANMET researchers also carried out bench investigations as well as in a continuous mixer-settler circuit the optimization of solvent extraction with emphasis on the characterization of cruds and methods of formation, the recovery of solvent from crud, and the examination of possible techniques to prevent crud. A combination of dissolved and suspended solids, and the relatively high shear produced by the mixer together contributed to crud formation, especially in the extraction circuit. Poor control of the ammonia addition and high shear produced the stable crud in the stripping circuit.

CANMET continued a cooperative program with Eldorado Nuclear Limited to develop and test a pilot-scale continuous ion exchange process for the recovery of U_3O_8 from Beaverlodge minewater. This also included a large scale study of the single-stage deep fluidized-bed, continuous ion-exchange column developed at CANMET. Improvements in the continuous ion exchange pilot plant to improve elution and resin transport resulted in reducing the uranium in the minewater from 9 to 0.5 ppm. Prior removal of calcium was the significant factor for uranium extraction, but it was impossible to optimize the flowrate because of a limiting capacity for the removal of calcium from the minewater prior to the continuous ion exchange step. Development of continuous ion exchange technology at CANMET is completed and a contract was awarded to industry to attempt to commercialize the process, which will include the study of axial mixing and channelling in the fluid bed.

A project to remove thorium from uranium barren effluents to meet environmental requirements, by solvent extraction using Primene JMT, was successful. A strip liquor containing 3.75 thorium per litre was obtained using 1M NaCl and 0.1M HCl. Further research is designed to produce a solid stable thorium product. Analytical development studies began on the application of high pressure liquid chromatography on microparticular ion-exchange packings for the rapid separation and determination of small amounts of individual rare-earth elements and other elements in ores and residues. Detection is by UV-visible spectrophotometry, and initial research is to evaluate the feasibility of this approach by separating nanogram quantities of copper, nickel, zinc and cobalt on a 10 µm banded-phase ion-exchange column. Future research will involve the determination of the optimum conditions required for the separation of the individual rare-earth elements using hydroxyisobutyric acid as eluant.

Several alternative options are being investigated in the search for new technology to replace conventional sulphuric acid leaching in uranium extraction. High recoveries of uranium, radium-226, arsenic and nickel were obtained from bench-scale chlorination roast-leach chlorination tests on a complex uranium ore from Saskatchewan. These tests were conducted to determine the optimum roasting temperature and hydrochloric acid concentrations. Further investigation will determine the effect of two-stage leaching, extended contact times and increased S/L ratios. The reactions of some nickel minerals with chlorine were investigated along with the development of the chlorination process for treating uranium ores containing nickel from Saskatchewan. This study using differential thermal analysis to investigate the interaction of nickel minerals with chlorine gas also included an examination of the effect of sodium chloride and pyrite on the chlorination process. Hydrochloric acid leaching of uranium ores and concentrates from Madawaska Mines and Gulf Rabbit Lake also resulted in high recoveries of uranium, radium and thorium. Favourable results were also obtained from leaching of a concentrate of low-grade Agnew Lake ore produced by a combination of flotation and high intensity magnetic separation techniques. A comparable leach was performed on a similar type of concentrate from an Elliot Lake ore, which yielded good recoveries of uranium, thorium and radium-226. Chlorine assisted leaching of Rabbit Lake and Key Lake ores also resulted in high recoveries when hydrochloric acid was used in the second stage of these two-stage leaches. The development of a stagewise removal of uranium, thorium, rare earths and radium from the chloride leach solutions is continuing but initial recovery of uranium by solvent extraction with Trioctylphosphine oxide appears promising. A novel stripping technique was developed for uranium recovery in this process, and it will be evaluated in a continuous circuit. Studies on the removal of radium-226 in the presence of calcium, magnesium and iron cations from chloride liquors were performed by batch and columnar contact of sulphonic-acid type resins. The purpose of this project for which a report was released, was to determine whether federal environmental regulation levels of radium-226 could be produced.

Nuclear Waste Disposal - CANMET continued participating in the Canadian Fuel Cycle Waste Management Program and in particular the igneous Geotechnical Sub-Program which is in its verification phase. Personnel from the Mining Research Laboratories and the Mineral Sciences Laboratories applied their expertise in rock properties, rock mechanics and underground engineering to studies on the development of sites for nuclear waste disposal. Investigations continued on potential sites at Atikokan and Chalk River Ontario, and Pinawa, Manitoba.

Research studies continued on the mechanical and thermal properties of core samples from these areas to provide data to aid in the selection of a suitable site and the design of a repository. Measurements of thermal elongation, diffusivity and conductivity as well as thermomechanical stability were completed on these specimens to relate the non linear dependence of elongation on temperature in establishing heat induced stress levels and displacements. Factors such as composition, texture, fracture state and pressure are also being studied, and experimental methods are being developed to cope with changes in situations regarding nuclear waste disposal.

The cooperative study with Lawrence Livermore Laboratory was continued to develop an experimental method of studying the effect of triaxial constraint on thermal diffusivity. Discrepancies between predicted and measured experimental results established the need for more extensive study of thermal properties under a wider range of ambient conditions. Confined thermal elongation measurements are being carried out on the Pinawa and Atikokan formations to determine the effects of pressure on the measured coefficient of thermal elongation. Additional high temperature triaxial studies were completed with this special equipment on approximately 50 samples from formations at Pinawa and Creighton.

CANMET researchers continued their studies with the new high pressure and high temperature permeability equipment, investigating the effect of temperature and pressure cycling on rock matrix permeability. Further studies are being carried out to assess the remnant effects of temperature and pressure on long term rock mass stability through porosity and permeability measurements.

Studies using analyses of thin sections were carried out on temperature and pressure cycled samples to assess the fracturing potential of the various granitic formations being investigated and the effects the fracturing could have on hydraulic transport. A special apparatus was designed, constructed and tested in the Rock Mechanics Laboratory for these investigations. The dead-weight compensator is being used in tandem with existing high temperature and high pressure triaxial and permeability units to control excessive pressure fluctuations during high temperature tests. Initial specimen size studies were completed with Pinawa granite samples using the new high pressure mercury porosimeter. Additional investigations are being carried out to provide pore spectra data for determination of rock matrix hydraulic conductivity and ion transportation by diffusion. A helium porosimeter and Hesler sleeve air permeability equipment were relocated to Ottawa from Elliot Lake Laboratory and is being used at Rock Mechanics Laboratory to extend the measuring capabilities of the existing porosity and permeability units.

CANMET scientists are studying relevant literature to ensure that technology will be ready to effectively seal off the repository and isolate the nuclear waste from surrounding formations and the environment. This information was used in a study to estimate the hydrogeologic transport properties of average undisturbed crystalline rock formations and the change of transport properties as a result of shaft sinking. This study was extended to estimate the achievable level of hydraulic conductivity with grouting and reports were written summarizing the research results on the long term stability of emplaced grouts. Considerable effort concentrated on plans for developing an underground research facility at Whiteshell, Manitoba. CANMET is participating in the committee preparing documentation related to this underground experimental program. The thermal rock property investigation this year, focussed on conducting detailed laboratory studies on core samples from the operating level of the proposed underground research facility in the Lac du Bonnet batholith. Planned research activity is being concentrated on standard sample studies from Atikokan and underground research laboratory site cores and lithologies, including triaxial studies and thermal elongation measurements. Studies are being undertaken on changes in fractured rock permeability under ambient conditions of temperature and pressure. Also, the detailed thermal property investigation is being continued on the proposed underground research facility. Large scale field studies are planned for next year, on the Lac du Bonnet pluton to establish the roughness characteristics of the principal joint sets. The results will be combined with laboratory studies on fractured rock samples to develop models for predicting joint set behaviour under changing stress conditions in terms of rock strength, displacement and dilation.

Renewable Energy Resources

Canada has abundant alternative, renewable energy resources available from wood and wood wastes. The use of wood to reduce demand for premium fuels in domestic heating has grown rapidly over the past five years. Indications are that this trend to wood heating is likely to continue as a result of major price increases for the premium fuels. The eligibility of wood-fired appliances for rebates under the Canadian Oil Substitution Program is making it very attractive for many people to convert to systems using potentially renewable fuel. Scientists at CANMET's Combustion Research Laboratory are applying their experience in solid fuel consumption to study the technology of wood combustion.

Although wood is rapidly gaining popularity, there is increasing concern over emissions of carbon monoxide and hydrocarbons due to incomplete combustion. These are significantly higher than those from oil or gas furnaces in good operating condition. Also polycyclic organic matter, some forms of which are known to be carcinogenic, has been identified in wood smoke. Heating efficiency can be improved by reducing these emissions because products of incomplete combustion also represent heat loss. CANMET has been developing a technique for measuring efficiency by a continuous heat loss method to determine effects of furnace design on heating performance in order to recommend better designs to Canadian manufacturers. The most efficient units were those with side draft combustion designs, and to a lesser extent, horizontal baffle designs, providing increased heating efficiency with decreased emissions.

The Canadian Standards Association (CSA) was awarded a contract to determine safe design and operating conditions of an add-on wood furnace for use with existing warm air oil furnaces. There was no standard for add-on furnaces until 1981, and several unsafe designs were being actively marketed. CSA developed an equipment performance standard based on the results of this study to allow series connections with the existing furnace. Approximately 15 units have been approved since September 1981, and the owners are now eligible for a rebate under the Canadian Oil Substitution Program.

The fireplace insert is also ineligible for grants under the off-oil subsidy due to both safety and efficiency considerations. Field trials indicated some inserts may be less than half as efficient as free-standing stoves. Poor performance was caused by heat escaping through masonry on outside chimneys and up the stack due to poor heat exchange characteristics, and by high levels of unburnt combustible due to poor combustion zone design. The Centre for Energy Studies, Technical University of Nova Scotia completed a research contract and prepared a report defining the relative efficiency performance of an insert in a masonry fireplace with outside chimney using four criteria: plain insert; insert with circulating fan; insert with circulating fan and outside casing insulation; insert as free-standing stove in a room. This work shows promise of leading to the development of criteria under which a well designed insert could be built which would be eligible for the federal grant.

Research efforts were directed specifically to the use of alcohols as an automotive fuel in Canada. Results are not conclusive that their use in automobiles is the best way to realize fuel economy. The use of methanol as a gasoline mix type of gasohol has problems of separation in Canadian cold weather which can both decrease fuel economy and increase emissions. There is a possibility that methanol can be substituted for home heating oil which is essentially the same as diesel oil used as automotive fuel. This plan could free diesel fuel, increase our automobile fleet economy, and give methanol a derivative energy efficiency. Experiments conducted on methanol indicate that it can be burned in conventional oil furnaces using a flame retention head burner, at steady state efficiencies of about 80%. Low excess air levels, below 30%, can easily be achieved with commensurate low emission levels. There were low steady state emissions of carbon monoxide and hydrocarbons, and carbon monoxide is the best measure of proper burner air setting. Efficiency was practically unaffected by excess air, below 50% surplus, for furnaces fired with methanol. The major heat loss is due to the hydrogen in the fuel, which is from 1.5 to 3 times the sensible heat loss for conventional furnaces. Continuing research is required to develop a pump suitable for long-term operation with methanol, which has low lubricity and high corrosion potential. A condensing furnace for methanol was described which offers the potential for seasonal efficiencies above those for similar gas-fired systems now under development. A condensing boiler fired with methanol might offer even greater advantages.

MINERALS RESEARCH PROGRAM

CANMET contributed to three of the activities included in EMR's Minerals Program for 1981-82 as follows:

MINERAL RESOURCE DETERMINATION
- Technical Evaluation

MINERAL TECHNOLOGY DEVELOPMENT
- Mining
- Health and Safety
- Equipment Safety Certification
- Mineral Processing
- Conservation of Minerals and Metals
- Environmental Technology
- Materials Development
- Metals Processing
- Standards and Specifications

ADMINISTRATION OF THE CANADA EXPLOSIVES ACT
- Authorization and Testing

Their main objectives as defined by EMR are:

(a) To provide an adequate knowledge of Canada's mineral resources for the development of policies and programs regarding the exploitation of those resources and to encourage and facilitate their orderly development.

(b) To ensure the availability to Canada of adequate technical capability for the supply, processing, and use of minerals.

(c) To administer the Canada Explosives Act in the interest of public safety.

MINERAL RESOURCE DETERMINATION

Technical Evaluation

A strong technological base is essential for establishing and maintaining a viable and competitive industry for the exploitation of Canada's mineral resources. CANMET is developing that base in a number of fields, which are reviewed below.

Complex Sulphide Ores - Work continued on the determination of the mineralogical character of the copper-lead-zinc-silver sulphide ores of New Brunswick and a comprehensive report on the mineralogy of the Caribou deposit of Anaconda Canada Exploration Limited was completed. Cores recovered from recent drilling were examined and sampled and it was shown that the mineralogy of the material intersected in 10 new drillholes is compatible with the known characteristics of the Caribou deposit thus it does not represent a new sulphide body. The reopening of the 6200 level provided an opportunity to study the development of secondary minerals by oxidation, as it is important to know whether in situ alteration is proceeding at a significant rate.

The study of the remaining deposits sampled in the Bathurst area is continuing. The laboratory work on the McMaster deposit is complete and the studies on the Rocky Turn, Orvan Brook, Murray Brook and Restigouche deposits are well advanced.

Lead sulphantimonides are common carriers of minor elements in the New Brunswick massive sulphide deposits therefore more data were acquired on some of these important minerals.

Mineralogical research continued on the behaviour of minerals during grinding and flotation using image analysis. Materials collected from the processing plant of Brunswick Mining and Smelting Corp. Ltd. (BMS) were used and the results applied directly to the present operations. Several technical papers were published on complex sulphide minerals.

Platinum-group Minerals and Precious Metals - A major achievement was the publication of a book "Platinum-group elements: mineralogy, geology, recovery", which included chapters on inorganic chemistry, phase relations, geochemistry, sample preparation, analytical methods, types of deposits and recovery from ores, as well as tables and descriptions of the platinum-group minerals.

Research on precious metals is being restricted to the recovery of gold from tailings associated with gravity separation plants because tailings from cyanidation plants normally contain little gold, which may be further depleted by residual cyanide. The initial study was restricted to Nova Scotia because there had been a large active gold mining industry in the latter part of the 19th century when stamp mills with amalgamation were common.

Canadian Silica Resources - It is important to identify Canadian silica deposits that have potential for the economic recovery of silica sand for the glass, glass fibre, artificial abrasives, silicate chemical and foundry industries. Canadian requirements for silica sand are largely met by producers in the northeastern United States. Imports exceed 1 Mt/a, whereas Canadian production of high-purity sand is in the order of 600 000 t/a. Increasing concern by both industry and government regarding present and future sources of high-purity silica sand necessitates a detailed study and evaluation of the more promising silica deposits occurring in southern Quebec and Ontario.

A study of available reports identified potential areas in eastern Ontario. These areas were drilled and core sample studies and laboratory tests began in September 1981.

Non-ferrous Pyrometallurgical Slags - This project was undertaken to develop methodology to reduce the loss of valuable metals such as nickel, copper, cobalt and precious metals in slags while increasing the rejection of undesirable elements such as arsenic, bismuth and antimony.

Many concentrates of copper, nickel and lead sulphide ores contain minor amounts of valuable metals such as cobalt, precious metals, molybdenum and zinc, some of which may be lost to the slag during pyrometallurgical smelting. Methods for decreasing these losses or for recovering the metals before the slag is discarded would help conserve Canadian mineral resources. One possible route for rejection and discard of unwanted elements would be to collect them in the slag which, when cooled, would hold these elements in a relatively immobilized form.

An extensive literature survey on losses in non-ferrous pyrometallurgical slags is underway and the effects of slag composition on the physical properties of melts was reviewed. The influence of various metal production techniques on slag composition was studied and the mineralogical composition of slags and the extent of metal losses were considered.

Slag cleaning processes, also included in this review, are becoming an integral part of metal smelting practices and have proven commercially significant.

Laboratory work began on the distribution of silver between non-ferrous pyrometallurgical slags and the corresponding matte or metal phases. Also, a number of synthetic silver-bearing copper, nickel and copper-nickel sulphides were prepared and used in this study. Several of the experimental variables have been studied with respect to matte smelting, converting and slag cleaning.

British Columbia copper concentrates are often relatively rich in molybdenum that is not recoverable and can represent a loss of about 10% Mo in the initial (Cu + Mo) concentrate. A slag cleaning process, to be applied in the copper smelter, would be useful.

The distribution of molybdenum between phases in the smelting operation is being examined with a view to possible process design for which laboratory-scale equilibration experiments have been conducted.

Primary Mineral Wastes - Approximately 600 Mt/a of mineral and mineral-based wastes are produced in Canada by the mining, mineral processing, metallurgical and chemical industries. Some wastes are of interest as raw material for construction and building purposes and some contain significant quantities of potentially recoverable minerals. Since these wastes have already been mined, crushed and ground they may be recovered and reprocessed at low cost. Re-use of wastes will directly aid resource conservation. A compilation of data on these wastes was completed and published in a series of CANMET reports entitled "Mineral waste resources of Canada".

Cost recovery work included slag viscosities, beneficiation of offshore sands and the reprocessing of gold mine tailings.

MINERAL TECHNOLOGY DEVELOPMENT

This activity encompasses EMR's responsibility for performing, funding and coordinating mineral R & D in Canada as well as acquiring and transferring foreign technology to industry. CANMET is a major contributor as the department's centre for R & D related to mining, mineral processing and the conservation and utilization of mineral-based materials.

Mining

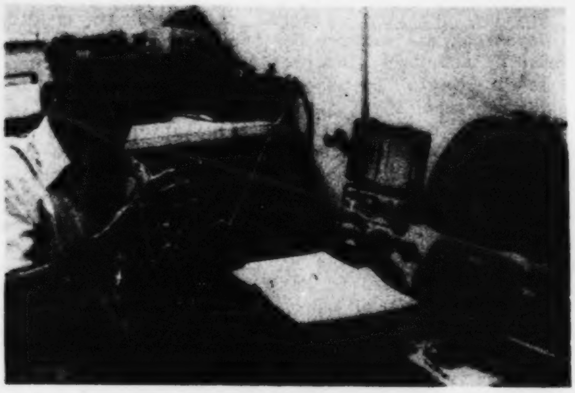
This sub-activity pursues and furthers the advance of technology necessary for increasing the efficiency of underground and open pit operating mines.

Regional Mine Stability - The cooperative research program initiated in 1979 by CANMET, Rio Algom Ltd., and Denison Mines Ltd., continued to investigate regional stability problems in the Elliot Lake uranium mines. Guidelines have been established on mining layouts and sequence of extraction near property boundaries so that the mining operations of one company are not detrimental to others. A study was undertaken to evaluate sill pillar recovery methods using displacement discontinuity computer models. The sill pillar was finally recovered without any undue problems after using the recommended method, which optimized roof and pillar stability.

At the request of mining companies and regulatory agencies an evaluation was made on possible stability problems underground, if mill tailings were disposed in Quirke Lake directly above the mining operations. It was concluded that this would not pose additional stability problems.

Further research on regional stability was postponed to concentrate on local stability problems associated with exposed roof faces in the Elliot Lake mines.

Design Guidelines for Deep Hardrock Mines - A major research program was initiated to investigate



W. Zawadski, technologist explains a new development in rock mechanics instrumentation for measuring underground stresses

rock mechanics and interrelated mining technology capable of improving both the safety and the economics of mining orebodies below 1000 m. Traditionally, cut-and-fill methods were used, which are incremental in nature in that relatively small slices of ore are drilled, blasted, cleaned or mucked out and the void backfilled with waste in a repetitious cycle. During this cycle miners are exposed to unsupported rock masses, particularly when they are installing supports after each cut. A few mines have been experimenting with bulk mining methods which involve pre-drilling the whole stope, blasting large tonnages and mucking continuously, but only backfilling the stope on completion of mining. In such cases, the miners work in well supported openings and do not enter the stope during active mining, thus productivity is higher and costs are lower compared with cut-and-fill methods. Bulk mining methods are being introduced on a trial-and-error basis and have been heavily dependent upon successful extrapolation of experience gained from mining at shallower depths. No formal engineering designs have yet been developed in Canada that consider the rock mechanics aspects of bulk mining at depth.

CANMET entered a joint project with INCO Metals Co. to develop guidelines for bulk mining methods at the Copper Cliff mine (CCS) in Sudbury. Initially, research concentrated on the rock mechanics aspects of blasthole stoping at moderate depths (300-600 m), where the rocks should still behave elastically. Geotechnical investigations have included structural geological mapping of the stopes, in situ stress measurements both remote from the mine workings and within the pillars, drilling core samples up to 25 cm in diam and laboratory testing to determine strength and mechanical properties of the rocks. In conjunction with this, the displacement discontinuity computer model has been modified to incorporate compressible pillars and the effects of backfilling.

Following two previous cost-shared contracts with Falconbridge Nickel Mines Ltd., a third contract was initiated in 1980 at the Onaping mine near Sudbury to cover an actual bulk mining trial to demonstrate the feasibility of using blasthole stoping techniques. Ground support systems were designed specifically for this program which were monitored using a full range of rock mechanics tools including computer programs for appraising the results.

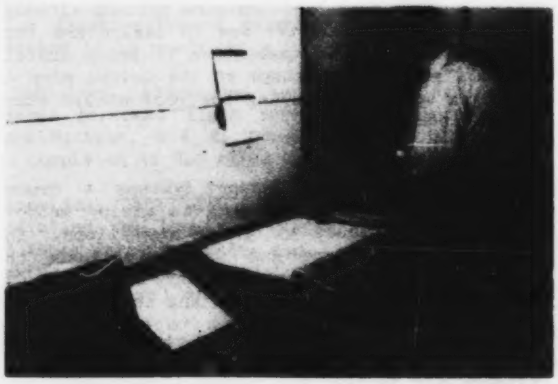
Another important aspect of bulk mining is the extraction of pillars between previously backfilled stopes. The free-standing height of the backfill is critical in preventing serious dilution when the broken ore is drawn down. A computer program, previously developed under contract, was modified and adapted to predict maximum free-standing backfill exposures.

Model Development - Computer modelling to develop, upgrade and improve the user manuals on numerical procedures for stress analysis of mine structures and other mining-oriented application packages continued.

To make working conditions safer and maximize the economical recovery of Canadian resources it is desirable to develop numerical techniques for predicting ground behaviour in deep mines where rock pressures increase.

A joint project was undertaken with INCO to develop and modify numerical procedures in an existing computer program. Several beneficial changes were incorporated: compressibility of pillars, backfill capability and off-reef stress/displacement capability. A preliminary assessment produced encouraging results. Full-scale modelling of the CCS panel using measured stresses and material properties is underway.

Another major project was the evaluation of Mining Research Laboratories' (MRL) computer requirements for numerical model development and associated applications in the Canadian mining industry.



N. Toews, scientist uses Tektronix plotter

Graphics used at Mining Research Laboratories: (L to R) 4014 Tektronix terminal; Versatic 1200 hard copy device; 4663 Tektronix plotter; Digital VT131 terminal

Underground Mine Stability - CANMET, Denison Mines Ltd. and Rio Algom Ltd. initiated a joint project to evaluate monitoring systems for roof collapse and to determine whether they are capable of providing adequate warning of impending roof falls in the Elliot Lake uranium mines. Instruments were installed in the roof of special test stope and controlled roof failure was initiated at Denison mines in 1981.

The necessary monitoring equipment in place, specially designed explosive charges were used to cut rock bolts to remove ground support in three stages. More than 500 bolts were destroyed and additional rock stress was introduced by connecting the compressed air line to a packer in one of the boreholes in the roof and the fracture systems were pressurized to 276 kPa. Finally a pillar separating two stopes was blasted tc remove direct roof support. This programmed destruction only resulted in bringing down about 200 t of local loose rock since the main roof structure remained stable. However, the instrumentation indicated internal rock stress and pressure buildup although results were inconclusive due to damage and loss of instruments. Instrumentation is being installed in a second test stope at the Quirke mine of Rio Algom and destabilizing the roof should start in June 1982.

Material Properties and Support Systems - Ground support systems vary according to mining method, excavation technique, and ground conditions. The objective of this research was to evaluate the effectiveness of underground support systems now used in deep mining situations and to provide additional technical information to assist in the development of mining methods for deep hardrock mines. This work was done in conjunction with the research into bulk mining methods undertaken by CANMET and INCO at the Copper Cliff South mine near Sudbury.

Diamond Drilling - CANMET continued to provide technological support for the diamond drilling industry and thus, indirectly, to Canadian resource development. The major research needs of the industry were identified in cooperation with the Canadian Diamond Drilling Association (CDDA) and included hardware items, data logging instrumentation and a waterline-heater for improved operating efficiencies, as well as studies involving hole-deviation and excessive noise at the drill sites.

Research concentrated on the latter when a contract was awarded to Heathwood Engineering Associates of Kirkland Lake, Ontario and Noranda Research Centre of Point-Claire, Quebec, under the guidance of a steering committee composed of representatives of the diamond drilling industry, Mines Accident Prevention Association of Ontario, project contractors and MRL. The contract called for: identification of the types of drills most widely used, determination of the decibel levels of the major noise sources of one of these drills, recommendations for the methods of attenuation of noise levels from these major sources with special reference to possibly retrofitting existing drills, and the examination and evaluation of other research efforts.

Health and Safety

Stringent controls on the working environment and the disposition of effluents from mining and processing operations continue to impose serious constraints on the industry. Research funds for these issues rarely show a positive return on investment thus industry tends to minimize such expenditures and develops short-term remedies. Long-term technology development to ensure proper solution depends on government initiatives therefore CANMET, in cooperation with other federal and provincial agencies, is a major contributor.

Dresser/Boyles BBS No. 15 diamond drill with Deutz diesel engine used in CANMET-sponsored noise evaluation test

Respirable Dust - Dust is a significant factor affecting both the comfort and long-term health of workers in all mining operations. Dust from certain minerals can lead to lung disease, particularly quartz (silicosis) and asbestos (asbestosis and malignancies). Lubricating oil mists and diesel engine exhausts carry noxious dust and gases. In uranium mines dust particles can carry solid radon daughters into the lungs and stomach where the alpha and beta radiation emitted internally may give rise to malignancies.

Instrumentation for determining personal exposure to respirable dust is well developed. However, there is a need to develop measurement techniques and programs to predict personal exposure and facilitate continuous measurement. The origin, composition, size distribution and other factors must be known to determine effective dust control measures and to guide and interpret epidemiological studies. This work requires the development of an extensive database through sampling in mines in cooperation with radiation and diesel emission scientists.

Control measures focus on improving rock breakage and handling techniques to minimize dispersion, filtration of airborne dust, wetting techniques, optimizing mine layout and ventilation. Optimum control requires appropriate dust suppression and control devices be built directly into mine equipment.

The computer controlled X-ray diffractometer has operated since October 1980. The system has worked well and the software is still being improved to deal with interference and absorption.

The combined workplace dust, ambient exposure and medical study at the iron ore mine in Labrador West has progressed according to schedule by collecting more than 8000 samples for silica and other analyses.

An optical system for monitoring mineral dust and determining scale factors for use with some minerals is available at the Elliot Lake Laboratory.

G. Knight, scientist conducts X-ray analysis of SiO_2 in mine dust samples

G. Knight, scientist explains the operation of the dust chamber for checking the operating characteristics of dust monitoring instruments

A high sensitivity optical asbestos dust sensor is presently being developed under contract.

Assistance is being given to industry and universities in maintaining gravimetric sampling programs (Rio Algom, Denison, Quebec Cartier and Eldorado) and in developing capability in X-ray diffraction analysis.

Radiation - Research involved the development of instrumentation, radiation measurement techniques and health impact studies.

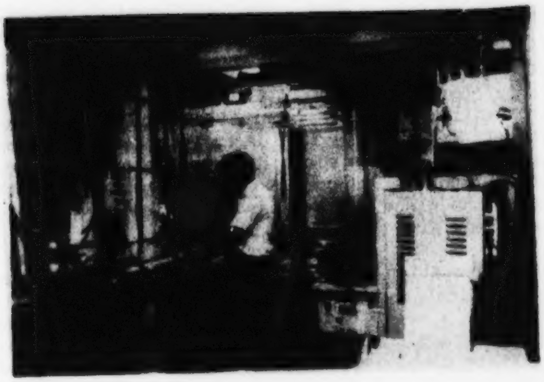
A meteorological package to operate with a radon gas continuous monitoring system was built to CANMET specifications under contract and is expected to be operational early in 1982. A contract was awarded to Alpha-Nuclear (Mississauga, Ontario) for the development of a quasi-continuous radon daughter/thoron daughter monitor which is expected to be ready early in 1982.

A long-term underground technical evaluation of several personal alpha dosimeters including the Alpha-Nuclear, H & H, Track Etch and TLD/CAMPED was completed at Rio Algom and Denison Mines Ltd.

Theoretical work including computer programs for predicting the levels of radon and thoron gases and their decay products, e.g., concentrations and working levels, was completed as well as calculations for several mine models.

Theoretical and experimental data taken from several underground uranium mines during the last three years were compared and part of the results were presented at an international conference on "Radiation hazards in mining", in Golden, Colorado, October 1981.

J. Bigu, scientist measures radon and thoron concentrations in uranium ore samples



J. Bigu, scientist prepares radon box for calibration of radiation instruments

Work was conducted on long-lived radioactive dust in underground uranium mines using alpha spectroscopic techniques. Background was derived from experiments and data collected in conjunction with the long-term personal dosimetry program.

Diesel Emissions Control - Work continued on providing a diesel machinery emissions certification service applicable to underground non-coal mines and other confined locations. Also, work continued on the stated aim to transfer diesel emissions reduction technology to industry by 1983 through the demonstration of a reduced emissions prototype machine.

A Memorandum of Understanding for the collaborative diesel emissions toxicity reduction program was signed by United States Bureau of Mines, CANMET, and Ontario Ministry of Labour in January 1982. This program is designed to demonstrate by 1984 the effectiveness of a number of equipment options by direct assessment of the beneficial impact on the underground environment. The means of evaluating the impact is the EQI/AQI criterion, which mathematically expresses the additive and synergistic aspects of the toxicity of the five major noxious components in diesel exhaust.

CANMET has been active in the parallel development of two diesel exhaust emission filters - a graphite-impregnated fibre glass cloth type developed in house and a ceramic honeycomb type produced by Corning Glass of Corning, New York.

Its smaller dimensions and relative ease of cleaning suggested that Corning's unit should be chosen for further development thus CANMET initiated a collaborative study involving Corning Glass, Walker Engineering, INCO and CANMET. This called for the installation of redesigned filters on a 5 yd^3 (4 m^3) scooptram powered by a Deutz F8L 714 series engine to assess the effects of two months of thermal cycling and mining vehicle inertial forces on the mechanical integrity of the ceramic system. Preliminary trials have been very encouraging suggesting that this is the most practical option for ultimate demonstration underground as well as being economically feasible.

The Volvo BM 861 U articulated truck is one of the few underground diesel units manufactured by an organization which shares the same corporate roof as the engine manufacturer. As a result it has provided an opportunity to study the characteristics of the entire system of turbocharged aftercooled engine, transmission and exhaust scrubber for emission levels. The performance of each component was evaluated by full-scale dynamometer testing and the overall effect of the various innovations was a 38% reduction in the recommended ventilation requirements relative to the bare engine, due largely to the 60% reduction in particulate matter brought about by the action of a Venturi scrubber.

The mining diesel fuel standard is virtually complete, except for the resolution of the debate over the wording of the flash point specification. In general, the use of regular fuels which approach the limits of the new standard can be expected to double the soot and sulphur dioxide content of the exhaust gas, and pose an increased flammability risk where rock temperatures exceed 30°C. Adoption of monthly low temperature specifications has significant implications for most operators in remote sites, e.g., fuel purchased in November is not likely to give satisfactory performance on the surface in January.

Noise and Vibration - In the last 10 years Canadian industry has made great advances in noise abatement and during the year CANMET, in cooperation with industry, has maintained a full program determining the noise levels to which mine employees are exposed and also assessing the new pocket dosimeters.

Instrumentation for obtaining noise level measurements

Action has been taken to protect miners' hearing, and noise measurement will eventually be completely automated and integrated with a computerized monitoring system. Thus, audiometric tests will take the same route. The use of a new generation of noise dosimeters will greatly contribute to workers' health, safety and productivity and to environmental impact studies.

Vibration, particularly localized vibration of the hand due to a powered tool, has recently been cited as a potential health hazard. The major concern stems from what is known as vibration-induced white finger (VWF). The main symptoms are intermittent numbness and weakness or clumsiness of the fingers, often coincident with blanching of the extremities in whole or in part. More acute cases can manifest temporary loss of muscular control in the extremities, intermittent paresthesia (weakness) or occasional burning pain.

These symptoms may develop after only weeks of exposure or may take years. However, relief is directly related to reducing the exposure to vibration. It appears that vibrations above 25 Hz are more responsible for this syndrome than lower frequencies. A safe amplitude has not yet been determined although the International Standards Organization is now developing a vibration standard. Therefore, it behooves manufacturers of hand-held power tools to attempt to reduce the vibration level to the minimum possible.

Explosive Atmospheres - The Canadian Explosive Atmospheres Laboratory (CEAL), the Canadian Explosives Research Laboratory (CERL) and the Western Office in Calgary continued to study the hazards associated with fire and explosion in coal mines in terms of ignition source control, early detection of spontaneous combustion and methane emission control. They also continued to participate in the development of suitable codes and standards for the effective control of these hazards.

With respect to ignition source control, CEAL is the only facility in Canada that tests explosion proof materials for use in hazardous gas locations, with emphasis on coal mines. Therefore, efforts have been directed to identify design criteria for such equipment to disseminate this information to Canadian industry.

Two specific flameproof projects were undertaken to provide design criteria for flameproof diesel water scrubbers, i.e., water-filled diesel exhaust cleaners. The first defined principles to minimize explosive pressures which in turn reduces the design pressures. The second, which is still in progress, is aimed at determining the stress levels of relatively large areas of thin flat steel plates that will withstand internal explosions.

Electrical equipment used in hazardous locations is often interconnected by conduits and fittings. Such interconnected enclosures can generate unusually high explosion pressures that can be prevented by using sealing compounds in fittings. Test results have led to recommending the application of sealing compounds and will be considered for inclusion in CSA Code C22.2 No. 30.

Many potential ignition sources are associated with flameproof diesel machines therefore it is important to control their construction by issuing standards describing acceptable equipment. During 1981 this process came one step closer to realization in that the CSA subcommittee responsible for drafting the Canadian code for regulating the use of underground diesel engines was established.

Significant progress was made in the design and construction of special test equipment pertaining to impact ignition, static charge ignition and conveyor belt testing. These, along with existing equipment, provide CEAL with more expertise.

With respect to the R & D aspects of coal mine fire and explosion hazard reduction, a methane/airflow single point monitoring system (Siegar Ltd.) has operated for the past year at a producing mine. A contract was negotiated for a trial of the multi-point environmental monitoring system developed by CONSPEC of Toronto.

Dust/Methane Explosions - CEAL continued to promote the means of maintaining safety in underground coal mines involving potential methane/coal dust explosions. This work included the classification of Canadian coal dust with respect to explosibility index and the determination of methane sources and balance in Cape Breton coal mines.

A study was made of the explosibility index of samples of Bienfait Coal Co. Ltd.'s lignite coal and char dusts which showed their relative explosion rates to be weak.

A study was made of the methane gas content of the Phalen seam at No. 26 colliery, Glace Bay, N.S. Results indicated that the ignition sensitivity of coal dust was higher than that of Western coal. The effect of the presence of methane on ignition sensitivity is greater for DEVCO No. 26 coal dust than for Pittsburgh standard coal dust.

The explosibility of coal dust samples from Forestburg coal mine was evaluated showing its relative explosion hazard rating to be weak.

A contract to study methane gas in Cape Breton coal mines was granted to Atlantic Coal Institute, Sydney, N.S. Fording Coal Mine Ltd., Elkford, B.C. is engaged in a feasibility study to determine the effects of hydraulic stimulation as an aid to coal degasification. At the request of B.C. Coal Ltd., estimates of the methane gas content of a coal seam were made at Harmer Ridge, B.C.

Equipment Safety Certification - CEAL continued to provide cost recovery services to industry including certification and testing of electrical equipment, diesel-powered equipment, non-flammable and anti-static materials, gas detection systems and fire-resistant hydraulic fluids. Also, general cost recovery research and testing were made in other areas. CEAL continued to supplement the certification service for equipment and materials used in underground Canadian coal mines by increasing safety of activities in explosive atmospheres, developing related equipment and participating in standards writing.

As a result of successful compliance with accepted standards, 50 certificates were issued.

A second training course for flameproof and intrinsically safe equipment was held in November 1981.

CEAL personnel were involved in the investigation of two marine disasters at the request of the Canadian Coast Guard the *Hudson Transport*, which caught fire on Christmas day in the St. Lawrence River, and the icebreaker *Louis St-Laurent*.

A new facility for full-scale testing of fire-resistant conveyor belts was completed. This is the only permanent facility of its kind in North America.

Members of the 2nd training course for the maintenance of flameproof mining equipment held in November 1981 at Canadian Explosive Atmospheres Laboratory

Technical assistance was given to the Beaver Company and their contractors for flameproofing several diesel powered machines that will be used for driving the entrance tunnels for the new Donkin mine in Nova Scotia.

In June 1981, the first meeting of the new Canadian Standards Association (CSA) Steering Committee for Electrical/Mechanical Mine Safety was held in Vancouver, B.C. There are now four technical committees under this new steering committee on each of which CEAL is represented.

Presentations were made to the Alberta inquiry into coal mine safety in June 1981.

A high level of activity in contract testing for CSA was maintained during which 35 devices were subjected to explosion tests.

Three designs of flame arresters for use in gas compressor stations were tested for the Alberta government. These units were suspected of being responsible for several gas plant explosions in Alberta and were all found deficient by CEAL.

Mineral Processing Technology

The objective of this sub-activity is to develop and promote technology for improving recovery and grade of ores and concentrates from Canadian mineral resources.

Mineral Processing Plant Simulation - Significant advances were made in the production of an expandable computer simulator of mineral dressing plants as a teaching and analytical tool for Canadian mill operators and equipment manufacturers. It would also contribute to the optimization of equipment design and operation.

In 1980, CANMET and industry initiated a joint 15-year program to consolidate and transfer to industry the concepts and methods of process simulation. Consolidation was undertaken in 1980-81, methodology transfer was addressed in 1981-82, and methodology will occur in 1982-83.

Hydrometallurgical Lead - A cooperative project is being conducted with the Canadian lead smelting industry with the USBM providing background information and experimental data. It entails the development of a hydrometallurgical process for the recovery of lead, silver and other valuable components from typical Canadian lead sulphide concentrates, and from residues generated in the extraction and refining processes being developed for complex bulk zinc-lead-copper concentrates. Although the principal need is to improve environmental conditions, the flexibility to treat lead residues from a variety of extraction processes is a desirable advantage.

Towards year-end, work began on leaching native silver and silver-rich complex sulphide minerals.

A literature review is being conducted on leaching high lead/silver residues to obtain information for the development of a recovery process.

Iron Ore Processing - The mineralogical and microstructural changes in thermally indurated green pellets produced from the Iron Ore Company of Canada (IOC) Knob Lake concentrates were studied by reflected light microscopy. Pellets indurated at various temperatures for varying periods and soak times were compared with products obtained by programmed firing under normal industrial processing conditions. Results showed that the rate of reaction of the constituents in the iron ore pellet is both a function of sintering temperature, time and heating and cooling. In general, the strength of the pellets improved with increased sintering temperature and soak time.

Further investigations were undertaken to determine the cause of pellet expansion at IOC processing plant at Carol Lake, Newfoundland. Examination of sintered pellets supplied by IOC showed a wide variation in microstructure and pellet strength, indicating a significant lack of uniformity in temperature and heating throughout the bed of pellets on the commercial sintering machine. The difference in pellet expansion or nonuniformity of strength suggested that maximum processing temperatures in the upper and lower layers of the pellet bed could differ by as much as 100°C.

A project was carried out with the Environmental Protection Service, Wastewater Technology Centre, Burlington, Ontario to develop methods for treating waste water from iron processing plants for recycling or disposal.

A literature survey on ore variability and grade control, along with recommendations that a geostatistical approach be used to improve present practices was circulated to industry. This initiated further cooperative work to determine whether the geostatistical methods would have given tighter and better grade control over both long- and short-term planning. A limited survey on alkali removal from magnetic ores covering beneficiation methods by flotation was published.

Ironmaking Technology - CANMET investigated test procedures for evaluation of iron ore materials on behalf of the Canadian Advisory Committee to International Standards Organization (ISO) Technical Committee 102 (testing of iron ores).

CANMET is developing methods to assess the behaviour of iron ore materials during high temperature reduction testing simulating blast furnace conditions. The low temperature disintegration test (LTD) is being adopted by Canadian steel mills and iron ore producers because test results relate directly to blast furnace performance. A recent laboratory study showed that small amounts of hydrogen impurities have a large effect on LTD test results and that hydrogen should be maintained at a constant level of about 2%. CANMET is now participating in a round robin testing of the LTD method which was organized by ISO.

Extraction/Refining of Complex Ores - Although New Brunswick has the largest reserves of zinc, lead and silver in Canada, their exploitation has been severely hampered by their complex orebodies. High recoveries, which are essential for the economic viability of many of the deposits, can only be achieved through the production of bulk concentrates which, because of complexity and relatively low grade, are not amenable to conventional extraction/refining processes. Development of a new extraction process is essential to recover economically the zinc, lead, copper, silver and other byproducts from the bulk concentrates, while minimizing environmental problems associated with the removal or disposal of pyrite and SO_2.

CANMET selected three processes for evaluation. A chloride extraction process is being investigated at CANMET and one each of two sulphate extraction processes is being investigated at Sherritt Gordon Mines and the New Brunswick Research and Productivity Council (RPC) under shared-cost contracts with industry and the Department of Regional Economic Expansion (DREE). CANMET is the scientific authority.

A DREE contract was issued to the SNC group to prepare a cost estimate for a 25-t/d sulphation-roast-leach (SRL) process pilot plant. The SNC estimated a cost of $20 million (1981 dollars), over a construction and operating time of at least three years. The SNC report was reviewed by a government/industry consortium which concluded that total escalated costs for the SRL process pilot plant would be at least $30 million.

Work on the modified pressure sulphuric acid (PSA) process to produce a high-grade high-recovery lead/silver concentrate from Brunswick Mining and Smelting Corp. Ltd. (BMS) bulk concentrate was carried out at Sherritt Gordon under a CANMET/Sherritt shared-cost contract. A modified PSA process is being tested for application with Anaconda Caribou bulk concentrate on a cost recovery basis.

Small-scale Leaching Studies - The ferric iron leaching of chalcopyrite from different localities was investigated. Chalcopyrite concentrates were leached in both ferric chloride and ferric sulphate media. When the leaching rates were corrected for the amount of $CuFeS_2$ in the sample, similar rates were observed for all 11 samples.

The factors controlling the dissolution of chalcopyrite in ferric ion media were investigated and work was completed on the leaching of a pyritic Zn-Pb-Cu-Ag bulk concentrate in ferric chloride media.

Leach parameters such as reagent concentrations, pulp density, temperature and residence time were verified and further optimized for maximum extraction of zinc, lead and copper from the BMS bulk concentrate during a series of pilot plant leach tests.

Solvent extraction of the zinc was carried out and bench work is continuing to optimize the scrub conditions to decrease the iron in the product.

The oxidization of ferrous to ferric in the recycle raffinate to leaching must be optimized in bench studies before further large-scale work is undertaken.

The factors affecting the composition and yield of mercury jarosite and the formation of lead jarosite in the presence of dissolved copper were studied. Two software innovations were made in support of the jarosite work. The source code for the computer programs TASE and DSPACE was refined to provide a more efficient and suitable printed listing for users. Also, a new computer program was written to enable the efficient computation of powder diffraction data.

Basic studies on the electrowinning of zinc from chloride electrolytes have continued and both the role of organic levelling agents and impurities in this process have been extensively investigated.

The literature on the electrowinning of copper, nickel and cobalt from aqueous chloride electrolytes was reviewed. Compact, coherent depositions can be produced for all three metals and commercial or major pilot plant operations are proving its feasibility.

Dry-way Chlorination-Oxidation Process - Development of a dry-way chlorination-oxidation process capable of recovering, as saleable products, at least 95% of the total metal values (including sulphur) from complex Zn-Pb-Cu-Ag bulk concentrates was initiated. It consists of a sequence of chlorination, oxidation, leaching, solid-liquid separation, solvent extraction purification or cementation, and electrowinning. In addition to possibly effecting high metal recoveries and high energy efficiency, the proposed process offers the additional advantages of producing elemental sulphur and ferric oxide, thereby circumventing SO_2 emission and pyrite disposal problems.

Laboratory and mini pilot-scale investigations to optimize the operating conditions for chlorination of BMS concentrate have been completed and results are encouraging. Upscaling of the laboratory testing was accomplished by designing a conceptual reactor to handle a concentrate throughput of 600 kg/min, which includes feed system, chlorinator, deferrinator and off-gas system.

Comminution/Beneficiation - Evaluation of techniques developed on BMS ore for the production of bulk concentrates from lower grade and higher copper content complex sulphide ores was undertaken. As an alternative to direct selective flotation, separation tests to facilitate higher recoveries, will be conducted on the bulk concentrate with the aim of producing separate copper, lead and zinc concentrates.

The design and development of mini-scale processing equipment for the 50-kg/h continuous process development unit (CPDU) also comes under this project.

A flowsheet was designed for a proposed 3500 t/d crushing and flotation plant which would produce 1000 t/d of bulk concentrate from BMS ore. Also, separation of CPDU-produced Heath-Steele bulk concentrate into copper, lead and zinc concentrates was tried using sulphur dioxide as lead and zinc depressant.

It was not possible to utilize cyclones as classifiers in the CPDU because the feed rate required for operation is many times higher than the pulp flow, however, an artificially high feed rate can be created and maintained by recirculating the cylcone overflow.

In working with complex, fine-grained sulphide ores it was necessary to size finely-ground test products thus two air classifiers capable of ultra-fine sizing were chosen for evaluation - the Alpine Multi-Plex Laboratory Zig-Zag Classifier 100 MZR and the Donaldson Acucut A-12 Laboratory Classifier.

Hyrometallurgical Process for Nickel/Copper - Development and demonstration of laboratory-scale hydrometallurgical technology for treating nickel/copper sulphide ores to yield elemental sulphur and a saleable or discardable iron product was initiated in response to concern over "acid rain". This work is expected to result in the enforcement of more stringent environmental regulations on SO_2 emissions and although reductions in emissions can be achieved by conversion to sulphuric acid, marketing and storage constraints make alternative long-term solutions for SO_2 control desirable. Long-term strategies involve developing concepts that produce elemental sulphur rather than SO_2 from base metal sulphide ores and particularly those for nickel and copper, where the sulphur to metal ratio is high.

Work is in progress on a cost-recovery basis to develop a method for determining fluoride in organic solvents using a fluoride ion-specific electrode. Also, a method for determining small amounts of tantalum in fluoride solutions containing niobium was investigated.

Conservation of Minerals and Metals

Mineral Insulation - Research continued on the development of more useful programs for the recycling of waste rock, mill tailings and metallurgical slags. Increased utilization of such waste will aid conservation of mineral and energy resources and contribute to environmental improvement.

The mineral wool industry of Canada is composed of many small independent producers that utilize the traditional blast furnace slag/cupola furnace for mineral insulation production. The cupola furnace has a number of disadvantages compared with electro-melt furnaces. Good quality mineral wool is produced in several European countries using more energy efficient and more environmentally acceptable electro-melt techniques. Electro-melting gives more homogeneity and the composition of the furnace charges are more easily controlled. In addition, fine as well as coarse raw materials may be melted, which allows for the recycling of waste shot.

Commodity Background Studies - CANMET frequently advises EMR and other government departments and agencies on technology related to the exploitation of mineral commodities. CANMET also undertakes to fill gaps in technology related to the husbanding of domestic mineral resources. To keep abreast of developments associated with mineral commodities on which there is no current research a critical review of the state-of-the-art was initiated for commodities including aluminum, chromium, manganese, phosphorus and zirconium.

A review was made of alternative sources of supply and substitute materials for alumina by summarizing CANMET's past investigations on domestic non-bauxitic and foreign sources of alumina.

A review of chromium technology indicated that several alternative technologies are available to make lower grade and low chromium to iron ratio ores more amenable to exploitation. There is need for site specific assessments of well identified domestic resources to determine the technological and economic viability of Canadian ferrochromium production. The study "Chromium - an imported mineral commodity", will be available in mid-1982.

Manganese is another imported commodity being reviewed by the Ontario Research Foundation, under contract to CANMET, to provide a technological overview. This contract will be completed in early 1982, when the results will be published.

CANMET contributed to the Mineral Policy Sector's study of phosphate in Canada by providing an outline of the occurrence and geological description of known deposits, particularly in eastern Quebec and Ontario, northern Ontario and southeastern British Columbia.

The study showed that technically many Canadian deposits can be upgraded to market specifications for acid grade phosphate by simple mineral processing techniques. This material would also be satisfactory for phosphate fertilizer and chemical manufacture and for the manufacture of elemental phosphorus. However, large-scale commercial production of phosphates is only possible through the development of massive deposits such as those found in the Cargill area of northern Ontario; thus additional studies on mining techniques, metallurgical processing and market opportunities are required.

Comments were provided on two potential byproducts of phosphoric acid - phosphogypsum and uranium - and on the availability of substitute materials, particularly for phosphates used by the detergent industry. Although phosphogypsum has been studied as raw material for gypsum products, the presence of low but significant amounts of radium effectively discourages its use. The recovery of contained uranium during the processing of phosphate rock is technically feasible and is practised at two plants in Calgary. There appears to be much interest in the development of substitutes for phosphate detergents, however, the ideal substitute has yet to be found.

Environmental Technology

Disposal of Uranium Mine/Mill Tailings - Research continued to develop methods to reduce the detrimental effects of inactive tailing areas so that they will require little or no intervention by man in the future.

Hydrogeochemical and chemical radioisotope investigations of the saturated and unsaturated zones of the tailings were carried out, and a recognizable soil profile was identified and developed. The results were published and research is currently underway to evaluate the established vegetation for update of soil contaminants.

The current development of recently discovered complex orebodies containing a wider range of pollutants and higher levels of radioactivity has accentuated the need to improve the existing technology for the containment and disposal of uranium mine/mill wastes. CANMET's role includes contributions to the development of new processing techniques for the removal of pollutants in the mill,

Y. Sleypen, technologist analyzes a sample of uranium mine tailings water for iron and the development of methods for the treatment of effluents and the stabilization of tailings.

Studies were made on the interaction between cellulose-degrading and sulphate-reducing microorganisms, conversion of municipal wastes into compost, enumeration of bacteria in tailings impoundment sites and chemical, physical and biological aids for the control of toxic effects of mine tailing and waste disposal schemes.

Control of Toxic Pyrometallurgical Emissions - A project was initiated to provide data on the form and distribution of major potentially harmful elements encountered in Canadian non-ferrous pyrometallurgical processes and to develop and evaluate economically attractive methods for controlling gaseous and particulate emissions. Sulphur, arsenic, mercury, lead, cadmium, selenium and tellurium, either elemental or as compounds, exemplify the potentially harmful emissions from non-ferrous smelters.

Materials Development Technology

The general objective is to improve the properties of materials derived from minerals and to expand their applications. Their enhanced utilization is seen as the important final link in the chain of minerals exploitation, having high impact on the previous steps of exploration, mining, extraction, processing and production for end use. Research is underway to improve the performance of metals in corrosive and abrasive environments, improve the weldability of metals, develop methods for measuring the fracture resistance of ductile materials, for measuring residual stress levels in structures and to elucidate relationships between microstructure and physical properties in engineering alloys. Also, research is being conducted to develop concretes for aggressive environments and for specialized applications, particularly through incorporation of waste or marginal materials, and to improve the performance of refractories for the steel industry.

M. Turcotte, technologist measures plant growth on surface rehabitation of uranium tailings

Abrasion-resistant Ceramics - A project was undertaken to develop wear-resistant ceramics for lining materials handling systems. The principle being pursued involves the addition of materials to stable, hard ceramics that will induce reversible changes during firing and thus reduce crack potential and increase wear resistance.

Other research projects included the development of thermal shock resistant ceramics and the characterization of the mechanisms of failure of refractories lining secondary steelmaking vacuum vessels to aid in developing improved specifications.

Lightweight Aggregates for Construction - A project to develop a sintering technique for lightweight aggregate production and to evaluate the mechanical and elastic properties of concretes incorporating these aggregates was undertaken. This included assessing the production of lightweight aggregates from vermiculite, perlite, pumice, coal mine shales, and non-load bearing and insulating concretes incorporating these aggregates.

Marginal and Waste Materials as Aggregates - Marginal and waste materials can be processed and used as aggregates where high quality is not needed. A preliminary investigation was undertaken to determine the use of waste mine rock as a source of aggregates for high-strength concrete. Results indicated that satisfactory high-strength concrete could be produced, provided excessive fines were removed from the parent material.

Since the quality of available ilmenite has declined, its market potential as a component of high density concrete has become very limited. A preliminary series of concrete mixes using superplasticizers has indicated that this approach may be a way of using lower grade ilmenite to achieve acceptable concrete densities.

Performance of Concrete in Canadian Waters - A study was made to evaluate and improve durability of conventional and innovative concretes and mineral binder systems in which Portland cement was partially replaced by non-conventional and less energy-intensive materials, particularly in the aggressive environments of Canada. This work included the study of the durability of Portland cement concrete structures exposed to waters typically prevailing in many rivers and lakes of Northern Canada and the performance and durability of large concrete test prisms exposed to aggressive marine environment at Treat Island, Maine.

Behaviour of Concrete at Sustained Elevated Temperatures - The growing use of concrete in complex industrial applications necessitates a better understanding and performance of the materials under various thermal loading conditions. Research was undertaken to generate strength data on the long-term behaviour of concrete from 75 to 600°C and to determine the possibility of improving high temperature performance through compositional modifications.

Waste Materials as Supplement to Portland Cement - To conserve resources and energy it is imperative that less costly, and less energy-intensive materials be used in the production of Portland cement and associated concretes. Cement is the most energy consumptive component of concrete. One tonne of Portland cement represents 42% of the total plant production cost therefore successful attempts to reduce the amount of cement in concrete could result in considerable savings. The most promising of the less energy-intensive materials for replacing cement are granulated slag, fly ash and silica fume. The energy required to produce granulated slag is estimated at only half that for Portland cement. Since fly ash and silica fume are industrial byproducts research was undertaken on these materials and on the potential use of limestone dust as a partial replacement for fine aggregate in concrete.

Corrosion of Steels in Soils - A survey of metallic corrosion problems in Canadian soils, commissioned by CANMET, revealed that underground failures of municipal water pipe in Canadian cities due to corrosion are reaching epidemic proportions. The problem is national in scope and of considerable financial consequence. A contract was let to study the water pipe problem in the city of Calgary, as an example of municipal experience. An interpretive history of past failures is being prepared to determine the operative damage mechanisms.

Abrasion-resistant Cast-on Coatings - Testing in an east coast fishery was completed on dragger shoe castings made of ductile iron protected by an abrasion resistant layer of chromium carbide on the wearing surface, using the CANCOAT technique developed at CANMET's Physical Metallurgy Research Laboratories (PMRL). A comparison with standard alloy steel shoes showed the coated shoes wore at about the same rate as the standard shoes.

Abrasion-resistant Plate Steels - An important cost consideration for the Canadian minerals industry is the abrasive wear that occurs in mining, processing, and transportation operations. Attempts to develop plate steels having improved abrasion resistance, weldability and toughness by means of controlled rolling and direct-quenching continued with the production of experimental steels. Eight different steels were tested under contract to compare their abrasion resistance with that of various commercial materials. These tests confirmed that for low alloy steels low-stress abrasion resistance depends solely on the hardness developed.

Under another contract, the potential demand for direct-quenched plate steels was surveyed. It was concluded that plate for abrasion-resistant applications has a low-volume specialty steel market that would not justify installation of direct-quench facilities.

Weld Mechanics - Since metal distortion and residual stresses are present in welded engineering structures, welding fabricators often must control distortion by expensive machining. Knowledge of residual stresses in welded structures is essential to determine the potential service life when failure due to stress corrosion, fatigue and brittle fracture is possible. A contracted state-of-the-art survey was conducted which recommended the finite element method as the only technique capable of predicting residual stresses and distortion. Further work will endeavour to apply this technique to the prediction of residual stress levels in single pass welds, and in the long term to multipass welds.

Repair and Reclamation by Welding - There is now a strong incentive to reclaim and repair failed or worn industrial components in light of increasing material and energy costs. The development of welding procedures for repair and reclamation is difficult because of the wide range of metals and alloys and the difficulties in determining inherent structural and mechanical property requirements in the field. Therefore CANMET initiated a survey under contract to determine the level of expertise in Canada. Results indicated much work is needed to generate and assemble information to develop welding technology. The development of a handbook was recommended.

Heat-affected Zone (HAZ) Toughness - The objective of this project is to develop micro-alloy plate steels having improved notch toughness in the HAZ of high heat input weldments. The primary application is in the seam weld of linepipe, however, the steels could also be used in marine and offshore structures. The work was done in cooperation with the Canadian steel industry and the identification of microstructural constituents was contracted out in part to Canadian universities. Results showed that notch toughness can be improved significantly through appropriate titanium and nitrogen additions.

Characterization of Weld Defects - The objective of this project was to determine the fatigue life of a pipeline with various types of defects. The project was a cooperative venture with Interprovincial Pipeline Ltd., Welding Institute of Canada and Techno Scientific Inc., however, the original impetus was given by the National Energy Board.

A computer program was developed for calculating the corrosion fatigue life of a pipeline. The final results of the studies are given in terms of allowable defect depths in a particular transmission pipeline for varied crude oil types and varied life expectations.

Plastic Flow, Fracture, and Stress Analysis - The project objective is to evaluate and develop test methods to measure fracture resistance of ductile materials and experimental and analytical methods to provide estimates of residual stress levels. Results of instrumented impact tests were compared witn measurements of nil-ductility temperatures of ship plate using fracture mechanics. An extensive review of state-of-the-art methods of residual stress measurement was written and experimental work is underway to use the hole-drilling technique to measure variations of residual stress with depth.

Portable X-ray Stress Diffractometer - PMRL is attempting to develop a portable X-ray stress diffractometer that will routinely measure stress accurately and quickly. The Department of National Defence has contributed substantially to contract funding. A survey was made of the potential marketability of the instrument and a North American market was predicted for 25 units at $100 000 each in the first year and 80 units per annum for the next three or four years.

Engineering Alloys - Strength and Toughness - This project was undertaken to explore relationships between microstructure and the mechanisms of yielding and fracture in various engineering alloys. Current work is concentrated on the microstructure, toughness and fracture behaviour of controlled rolled microalloyed steels using heat treatment, Gleeble weld simulation and Charpy tests in addition to dilatometry and metallography.

Non-leaded, Free-machining Steel - Phase I of this project was completed in 1981 which involved a critical review of the mechanics of machining, the role of inclusions, modern developments necessary to remain competitive and recommendations concerning research options. Phase II involves a detailed study of the effects of eliminating alumina inclusions by utilizing calcium deoxidization practice for strand-cast 1146 free-machining steel. Tests will be made by fast-speed machining with carbide tools and slow-speed machining with high-speed steel tools. Research will be extended to eliminate lead in leaded steels.

Metals Processing Technology

The general objective is to encourage improved processing of metals in Canadian industry to yield increased productivity, decreased pollution and energy consumption. Research is focused on foundry technology, metal forming, milling and improved processing specifically directed to materials for land, rail and sea transportation.

Intercritical Heat Treatment - Investigations continued on heat treatment techniques to improve the low temperature properties of plain carbon and low alloy steel castings. The technique consists of an additional step in the heat treating process. The intercritical/quench heat treatment results in a microstructure characterized by fine lamellae of ferrite and martensite, whereas the intercritical/normalize treatment refines the grain size. Heat treatment is used to either salvage castings failing to meet low temperature specifications or to meet more stringent specifications, without increasing the alloy content of the steel.

Filters for Ferrous and Non-ferrous Castings - Tests were carried out to evaluate commercial ceramic foam filters for casting aluminum, magnesium and copper-base alloys. Although effective in removing dross and certain indigenous-type inclusions, they occasionally break down creating other defects in the castings. Some success was achieved in coating steel wool filters to prevent iron pick-up in aluminum melts.

The ceramic foam filters could not withstand the high pouring temperatures needed for ferrous alloys; however a technique was developed to filter grey and ductile irons and is being evaluated using a special dual casting design.

Optimum Properties in Magnesium Alloy Sandcastings - The increased use of magnesium alloy castings in aircraft has called for stringent adherence to specifications to ensure that the required properties are obtained in specific areas of the casting. Separately cast test bars do not necessarily reflect the properties of the casting itself. Superior properties in the casting are achieved by proper manipulation of chilling and feeding in highly stressed areas. This research was directed towards determining the properties of magnesium alloy test pieces taken from critical areas of an actual casting.

Cast-in-place Copper Tubing in Copper Tuyeres - The conditions required to cast copper tubing directly in a copper tuyere were determined and a report written on the procedure. This technology assists Canadian non-ferrous foundries in the production of a new design of tuyere which is more efficient and more reliable and it is hoped that this will also assist in greater use of domestically produced tuyeres. Additional work was performed on reducing or eliminating porosity in the wall section to further improve quality.

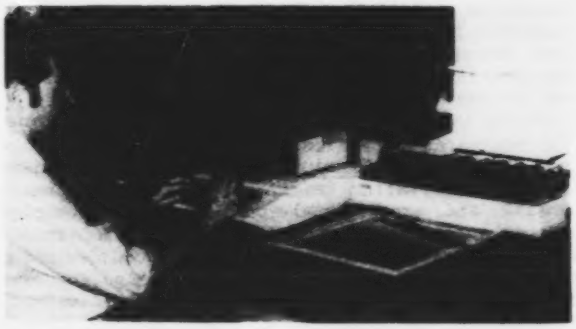
Cupola Melting Efficiency Survey - The goal of the cupola survey was to transfer to the foundry industry the technical and practical knowledge acquired by CANMET personnel during the first stage of the survey. Its application by Canadian cupola operators should lead to an industry-wide reduction in coke consumption of 3-5%, which would reduce expenditures on imported coke by at least $1 million per annum.

The primary method of transferring technology has been through the regional workshop, however, other activities have also played significant roles. A census of cupola operations in Canada was conducted by telephone, which in addition to providing accurate information on the number and productivities of foundries, resulted in the establishment of valuable personal contacts and the creation of an up-to-date computerized mailing list.

A major advance in foundry technology transfer has been achieved by the development of four microcomputer programs at PMRL, which greatly facilitate the analyses and control of cupola operations. The cupola software has been used at PMRL to ensure rapid and accurate responses to numerous requests for assistance and in the regional workshops for teaching and demonstrations. It will be subjected to intensive industrial trials prior to being offered commercially.

Based on information obtained from the efficiency survey and the foundry census, regional workshops were held in Edmonton, Alberta, Cambridge, Ontario, Trois Rivières, Quebec and Moncton, New Brunswick. Response to the workshops was far greater than anticipated thus two additional workshops were held in Cambridge and Hamilton, Ontario, respectively.

Grey and Ductile Iron Workshop - A workshop on grey and ductile iron was organized and presented by members of PMRL's Foundry Section assisted by three speakers from industry. The response was such that two workshop sessions were necessary. Topics included structure and properties of grey and ductile iron, inoculation techniques, cupola and electric melting practice, foundry sand, quality control, risering, high alloy cast irons, ductile irons and new technology.



L. Whiting, scientist writes a micro-computer program for use by foundrymen in analyzing cupola operations

Degradable Sand and Core Binders - The initial feasibility studies of the newly developed binder system for sand mould and core production were successful and prompted negotiations to find a contractor to more fully investigate the system from a commercial point of view and to investigate marketing. In addition, patent applications were filed and Program for Industry/Laboratory Projects (PILP) funding was obtained for the additional development costs. Pfizer Canada Ltd. indicated interest in the process and is formulating a comprehensive plan for full testing in commercial foundries.

Continuous Casting of Metals - The Ontario Research Foundation (ORF) was awarded a contract to design, construct and calibrate an apparatus to measure the friction characteristics of mould fluxes used in the continuous casting of steel. The apparatus was designed and constructed but not calibrated. The contract was completed but the apparatus was left at ORF because of industrial interest.

Inoculation of Iron Castings Made in Permanent Moulds - A gravity permanent mould casting machine was designed and constructed. A die design for this machine was also completed and both cast-to-size and machine dies were produced in grey cast iron.

Cast-to-shape Dies for Permanent Moulds - Techniques were developed in which permanent mould dies can be produced using cast-to-shape die cavities. The Shaw Process is used for the working faces of the die, which produces a surface that requires a minimum of preparation prior to use.

Testing of Die Materials and Coatings - Problems were encountered in obtaining a satisfactory apparatus design for combined testing of die materials and coatings. A dip-type test could be used in which the candidate material is regularly immersed and withdrawn from a bath of molten metal, with subsequent ejection of the solidified shell. Difficulties were encountered in consistently producing a solidified shell on the die in this type of test; therefore it may be limited to testing thermal fatigue properties of the die materials. For higher melting point metals there would be considerable problems in keeping a bath molten for long periods therefore this test may be applicable only for low melting point metals. An alternative technique using inductive heating of the test die material is being investigated.

Low Pressure Permanent Mould Castings - A fairly comprehensive program was undertaken to better understand the operation of the low pressure casting machine and the effects of the numerous parameters on the quality of the casting. Most of the work was performed on a relatively simple dish-shaped casting. Design of a more complex casting will be made and evaluated in the next fiscal year.

Mathematical Modelling of Heat Flow in Permanent Moulds - A contract for this work was given to Ottawa University and the first phase was completed. A preliminary mathematical model was developed to permit heat flow calculations to be made in a two-dimensional die in which cast iron is poured. The next phase will involve modelling of heat flow in three-dimensional dies of more complex shapes.

Electroslag Casting - Unforeseen problems in the site preparation have delayed this project. However, electroslag casting equipment using a single electrode was built and is operational. Water cooled aluminum moulds were produced in the PMRL Foundry in which the water-cooling channels were cast in place using the recently developed sand binder system. This technique should reduce mould costs significantly.

The servomechanism required for the production of thin-wall electroslag castings was designed under contract and the necessary equipment was purchased.

CANMET Foundry Newsletter - The Canadian foundry industry is kept informed of research at PMRL and of interesting foundry developments in general through the CANMET Foundry Newsletter.

Optimization of Rolling Mill Performance - A major undertaking was the design of a computerized system to automatically control the operations of mill roll screwdown, direction and speed, which would significantly increase the capability of developing production-efficient rolling schedules in the laboratory. The microcomputer currently used to acquire mill performance data was upgraded to increase computer speed and memory. Also circuit boards for process control were installed and computer programs were written for initial testing of key hardware and software elements. A system of relay switches was designed to replace the manual control system for automatic operation.

To increase the speed of the current mill gap adjustment system, a recommendation was made to replace the existing screwdown motor (top speed 700 rpm) with a new motor having a top speed of 1800 rpm in addition to position indication and regulation.

A second CANMET rolling mill technology seminar was held in May 1981 which was attended by about 90 representatives of industry, government and universities from Canada and the United States.

A three-year contract was awarded to McGill University to determine the causes and examine techniques to minimize the undesirable duplex grain structure which develops during controlled rolling of micro-alloyed high strength steels. The initial phase determined conditions under which grain coarsening and grain refinement occur during austenite deformation at high temperatures.

Influence of Microstructure on Formability - Tooling and instrumentation was installed and tested for limiting dome height (LDH), hole expansion and stretch bend testing. Existing computer programs for data collection and processing by tensile testing were extended to calculate and plot parameters which quantitatively describe the strain hardening behaviour of sheet metals.

Fluidized Bed Cooling - The fluidized bed designed and constructed at CANMET was applied in two stages. In the first, plates and rods of steel were immersed at ambient temperature to increase the cooling rate through the transformation temperature range to give increased strength. In the second, quasi-isothermal transformation was induced in suitable alloy steels at high temperatures to achieve superior microstructures and increased strength.

The first phase of the PILP contract awarded to Algoma Steel Corporation to examine the feasibility of on-line processing of shaped steel products using fluidized beds was completed. The study concluded that fluidized bed systems are technically and economically feasible for industrial processing of alloy steel shapes and for soaking pit operations for carbon-manganese steels.

Heat Treated Rail - Early work in the project focused on evaluating a spectrum of rail steel compositions that transform to the microstructure and hardness representative of the best of the current generation of premium rail. The objective of current rail research is to assess the feasibility of producing a rail having a microstructure that is incrementally harder than current premium rail. Specimens representative of rail are transformed in a quasi-isothermal manner at elevated temperatures in a fluidized bed. Research is concentrated on evaluating the properties of those steels which transform to a microstructure at the target hardness of R_c 44.

Thermal Processing - Progress was made in determining optimum operating conditions of a fluidized bed to produce a desirable microstructure of high hardness in plate samples rolled to thicknesses simulating rail heads. This work has been of considerable interest to one of Canada's rail producers currently planning a new rail shaping mill and who is contemplating installing a fluidized bed for heat treating rail.

Wear Resistance of Premium Rail Steels - Work continued on evaluating the wear resistance of commercial and experimental premium rail steels. This is a collaborative venture with the NRC Tribology Laboratory in Vancouver who have devised and constructed a rig which imposes scaled forces on wear specimens in the form of a pair of rotating discs, one machined with the profile of a wheel, the other with the profile of a rail. Disc pairs for testing have been heat treated at PMRL

V. Moore, technologist analyzes inclusions in a sample of rail steel using electron microprobe analysis

to give three different microstructures at each of three hardness levels, i.e., a matrix of nine. The microstructures of these specimens are characterized by optical and transmission electron microscopy being carried out under contract by the Technical University of Nova Scotia.

Automotive Materials - Work focused on certain aspects of dual-phased steels, i.e., the effects of a galvanizing thermal cycle on properties of continuously annealed dual-phase steels, the conclusion of research into the feasibility of producing dual-phase steels by batch annealing, and the development of a micromechanical model to further our understanding of these steels.

A contract was also awarded to McMaster University to study the microstructural features which limit formability in mass-produced cold forgings, such as wrist pins and fasteners. The ultimate objective is to separate the effects of microstructural features, such as inclusions, from the intrinsic material flow behaviour, to produce cold formed products from higher strength grade steels.

Marine Materials - Work is primarily aimed at providing the necessary information on materials to enable the construction of vessels which can successfully operate year round in Canadian Arctic waters. Proposals to develop the petroleum resources of the Beaufort Sea and the gas resources of Melville Island involve the construction of icebreaking ships to transport these resources to Southern Canada. To assist in defining the research needed to aid in the selection of steels for these vessels, discussions were held with representatives of the companies involved, a Canadian steel producer and the Canadian Coast Guard (CCG).

Work continued on the evaluation of samples of hull plate supplied by the CCG from ships operating in the Arctic and a summary report was prepared. Although fracture resistant steels are readily available it is apparent that most commercial ships are being constructed from steel that is not required to be impact tested, and all too frequently has an impact energy of less than 15 J at 0°C in a standard Charpy V-notch impact test. As part of this evaluation a 4-m crack in a 10-month-old Canadian ship was investigated.

Initial work was done on the welding of fracture tough steels using a high energy input one-sided submerged arc process. This will determine if adequate toughness can be obtained in the weld and HAZ using this high productivity process.

A review of the various specifications for fracture tough steels for possible use in Arctic icebreaking vessels was made, with emphasis on the suitability of CSA grades of steel.

Work continued on the corrosion of welds in icebreaking ships with the completion of an apparatus, patterned after one in use in Finland. Three grades of hull steel were obtained and specimens prepared to test various combinations of welding electrode and hull steel.

Four test racks of corrosion specimens, each containing 21 alloys, were placed in the Barrow Straits, south of Resolute, by the Department of Fisheries and Oceans (DFO) early in April 1981. As of May 1982, only one of the racks had been recovered, although DFO remained optimistic that two more will eventually be recovered. One rack of corrosion specimens was prepared for the Arctic Research Establishment at Pond Inlet for placement in Eclipse Sound during January 1982.

High-strength Copper-base Alloys for Shipboard Systems - Although research and development work on this project was the Department of National Defence (DND), the work is also of interest to CCG, Canadian Stone Marine Ltd., and other Canadian brass and bronze foundries.

The transfer of technology on Cu-Ni casting alloys was completed as well as work on the dealuminification of cast, and cast and welded, Ni-Al bronze alloys.

CCG icebreaker propellers, cast in Mn-Ni-Al bronze, tend to have low fracture toughness. After discussion with DND and CCG a project was initiated to identify the mechanisms responsible for the low fracture toughness of the sandcast propellers and to recommend industrially usable heat treatments to improve their impact properties. Canadian Stone Marine Ltd. assisted in the measurement of cooling rates of propellers.

Cupro-Nickel Casting Alloys - As part of a PMRL program to develop Canadian capability in the production of high quality admiralty castings, a 320-kg six-valve chest casting having certain auxiliary components was cast in a southern Ontario bronze foundry in niobium-modified 70/30 Cu-Ni alloy. Production of the casting to DND specifications was financed by DND. The radiographically sound casting passed the 2760 kPa water pressure test and was shipped to Montreal in the fully machined condition for shock testing. This hull-valve casting will replace an existing imported casting in a Canadian submarine.

Nickel-Aluminum Bronzes - Weldability studies of Ni-Al bronze casting alloys were completed and the importance of a corrosion-inhibiting heat treatment on welded specimens was demonstrated. Welded and post-weld heat treated specimens were supplied to the Dockyard Laboratory at the Defence Research Establishment Atlantic for corrosion studies.

Since Ni-Al bronze alloys are also used for casting ship and submarine propellers, work is underway to study their corrosion fatigue behaviour in sea water. To this end, fatigue-crack growth rates in standard laboratory specimens are being determined in air and salt water for both as-cast and cast/heat treated conditions.

Propellers for Ice Breakers - To examine the effect of composition on the microstructure and tensile and impact properties of Mn-Ni-Al bronze alloys, a number of concast rods and square bars of various manganese and aluminum contents were produced. Microstructure and mechanical properties of the alloys were studied in both concast and concast/heat treated (stress-relief heat treatment) conditions. The concast rods were heat treated to simulate microstructures representative of heavy sections in sand castings, such as those found in ice-breaker propellers.

Microstructure (X500) of a nickel-aluminum bronze alloy propeller showing iron- and nickel-rich kappa phases in an alpha matrix

Standards and Specifications

Development of Instrumentation and Techniques - As part of a program to replace obsolete electron optical equipment in PMRL a CAMECA MBX microprobe was installed and commissioned in 1981-82 to replace a 1965 model. This instrument has superior electron optics that will permit accurate analysis of areas of the order of one square micron for acceptably low counting times. A spectrometer equipped with a large lead stearate crystal permits analyses of elements down to boron. The microprobe is also equipped with an X-ray energy dispersive analysis system and a PDP-11 microprocessor to handle data and control the spectrometers.

Modern equipment for analysis of hydrogen will be installed early in 1982-83, replacing an old glass vacuum system using mercury, now judged to be a safety hazard. The analysis group is working on a method for hydrogen analysis which would distinguish between absorbed (molecular) and combined (atomic) species.

Certification of Nondestructive Testing (NDT) Personnel - Since 1960 PMRL has been authorized to certify NDT personnel according to CGSB standards by administering a system of practical and written examinations via a network of test centres across Canada. Implementation of a three-level certification system has continued, new standards on radiography and ultrasonics have been put into effect for three levels, and certification in eddy currents has been started for Levels I and II.

Reference Materials - The Canadian Certified Reference Materials Project (CCRMP) prepares and certifies samples of ores, concentrates, metals and related materials for use as compositional reference materials, by means of interlaboratory and in-house programs. The compilation of methodological information from these programs is an important ancillary benefit to CANMET and the analytical community. In 1981 CCRMP distributed approximately 1400 units of reference materials to users in Canada and abroad.

The Chemical Laboratory is also active in the analysis of reference materials and participates in the interlaboratory certification programs of other agencies such as the Council for Mineral Technology of the Republic of South Africa.

Analytical Methodology - An on-going project is the development and improvement of analytical methods, techniques and laboratory facilities to support CANMET programs and committees of national and international organizations that develop and disseminate information on standard analytical methods.

ADMINISTRATION OF THE CANADA EXPLOSIVES ACT

Authorization and Testing

The mandate of the Canadian Explosives Research Laboratory (CERL) is to confirm the safety characteristics of new explosives submitted for authorization under the Canada Explosives Act, to provide technical advice on the manufacture, storage and transportation of explosives and to investigate accidents involving explosives or similarly hazardous materials.

During the 60 years which the Act has been in force the laboratory functions of certifying explosives, advising on technical problems of explosives handling and investigating accidents involving explosives have continued to develop. The expertise in explosives safety engineering is developed in house through contact with manufacturers' research laboratories, contract research projects, in-house development projects and international contacts. The proprietary nature of commercial formulations and the results of individual examinations for authorization remain confidential.

Responsibilities under the project continue to increase because of technical advances in formulation, Canada's international responsibility as a major explosives producing country and the increasingly critical reactions from the Canadian public to accidents involving explosive elements.

Achievements - During the year 233 new explosives were examined for authorization involving 2059 samples. When compared with 1979-80 (238; 2400 samples) and 1980-81 (302; 2756 samples), indications are that certification is declining. However, the figure of 302 for 1980-81 was inflated by the large influx of samples resulting from the Produits Chemique du Valleyfield (PCV) accident in Valleyfield and in fact the number of explosives having been submitted for authorization has remained fairly constant over the last three years. This past year has witnessed a significant increase in the number of high explosives submitted for authorization and several new generation emulsion explosives were examined as well as slurry explosives and dynamites incorporating a number of new developments.

No major accidents occurred in manufacturing and it is noteworthy that the fire extinguishing system, which CERL helped develop during 1980-81, functioned during an accidental ignition. As a result there were no injuries and only minimal damage to equipment.

The fatal accident at PCV in August of 1980 raised a number of concerns about the use of semi-conductive plastics to dissipate electrostatic buildup. A major investigation by CERL into the properties of semi-conductive plastics showed that these materials can modify an electrostatic discharge so as to actually reduce the energy required for spark ignition of propellant dusts. Research into the properties of semi-conductive plastics which cause these effects is continuing.

Static slide for evaluating electrostatic generating capacity of granular materials such as propellants

As a continuation of work initiated prior to 1980-81 a number of detonator boxes constructed to CERL specifications were burn tested and capable of withstanding 1 h of intense heat before the detonators which they contained exploded. This indicates that in a fire situation involving a vehicle transporting detonators and explosives in this type of box the chances of the detonators exploding and initiating the explosive cargo are significantly reduced.

Work continued on the evaluation of a nondestructive tester for the bridgewires in detonators. Additional research included the determination of initiating strengths of a wide variety of commercial detonators and this work, which is being done in cooperation with the U.S. Bureau of Mines and C.I.L. Inc., will determine if slight differences in detonator base charges affect the initiating ability of commercial products. It is hoped that one or more of these detonators will be chosen as the standard test detonator for Canada and the United States.

CERL continued to provide informal technical assistance to private citizens, industry, and the RCMP.

Research and Development - The objectives of the 1981-82 R & D programs were: to make available a computerized system for predicting safety parameters of explosives; to complete the evaluation of hazards and ammonium nitrate; to determine the safety properties of the new emulsion explosives by 1984; to verify the United Nations classification procedure for incorporation into the Canada Explosives Act and Regulations by 1985; and to establish and thereafter maintain a routine Dust Explosion Hazard Laboratory by early 1982.

CERL purchased a CSI accelerating rate calorimeter (ARC) to study self-heating or thermal effects on reactive systems such as explosives. Newer generations of commercial explosives do not contain explosive sensitizers and depend on chemical or other means for initiation and propagation and therefore exhibit little or no mechanical sensitivity, but may have thermal or chemical instabilities due to the complexity of the chemical formulations of the explosives. This necessitated the study of the thermal decomposition of nitrocellulose using the ARC under various sample/bomb systems, heat-up parameters and atmospheres.

Work using the ARC for the next fiscal year will include decomposition studies of ammonium nitrate and other ingredients of explosives, and initial studies of emulsion and slurry explosive systems.

A contract for a research study to investigate and report on the fire and explosion hazard of ammonium nitrate was executed under the joint sponsorship of CANMET, Transport Canada and Industry, Trade and Commerce Canada, with support from the ammonium nitrate manufacturers under the coordination of the Canadian Fertilizer Institute.

Projectile impact tests on molten ammonium nitrate and ammonium nitrate-water solutions have shown that impact velocities in the order of 200 m/s are required for initiation and that the diameter of the impacting surface must be greater than the critical diameter of the material being impacted. Additional impact studies are planned as well as the effects of additives on the decomposition of molten ammonium nitrate.

A transient hot wire method was used for determining thermal conductivity of different types of slurry explosives in their natural packaged state and was found to be quick and safe.

The contract work for the modelling of ignition and buildup to detonation in slurry explosives continues. Two additional solid to liquid ratios were considered and the effect of gases other than explosive was investigated.

An examination of the Forest Fire Model and the energy criterion reveals that it may not be feasible to generate the critical energy criterion from the data of the Forest Fire Model, which is seen to be suitable for high velocity impact investigation.

Inner view of an accelerating rate calorimeter showing sample container, calorimeter and containment vessel - this instrument determines thermal hazards of energetic materials such as explosives

MINERAL AND ENERGY TECHNOLOGY INFORMATION

The production and dissemination of new information related to mineral and energy technology is one of CANMET's fundamental objectives. Although the provision of technical information is an integral part of the duties of the entire research staff, the formal aspects of technology information transfer are the responsibility of the Technology Information Division (TID).

The technical information program encompasses the following activities:

(1) Identification, selection and acquisition of relevant technical information from world wide sources to support requirements of branch research staff and to provide a comprehensive national mineral and energy technology information resource centre to assist research in Canada.

(2) Organization of acquired information; creation of a variety of indexes, catalogues and databases to facilitate access to information; and preparation and publication of reports detailing results of research performed at CANMET.

(3) Distribution of CANMET publications and those containing research performed under contract to CANMET; provision of technical information and advice to both public and private sectors.

INFORMATION RESOURCES DEVELOPMENT

During 1981-82 the library acquired 3295 monographic volumes in print and 6209 items in microform. Current subscriptions to periodicals in major world languages number 2490, an increase of 245 from the previous year. In all, 11 994 new items were added to the collection, bringing total library holdings at March 31, 1982 to 199 500 volume equivalents.

INFORMATION PROCESSING

The library's Cataloguing and Classification Unit was able to process only 87% of the newly acquired materials despite the unquestionable utility of the computer-based UTLAS catalogue support system introduced in 1980-81. As utilization of the computer-based system increases it is expected that the backlog will be cleared early in 1982-83.

The publicly accessible Mining Technology Information Database (MINTEC) continues to grow in size and in public acceptance. During the reporting period 1409 new records were added to the file, while the number of searches increased from 1500 in 1980-81 to 2326 in 1981-82. More than 1800 of these searches were performed by Canadian researchers not directly affiliated with CANMET.

The Mineral Processing Technology Database (MINPROC) containing more than 5000 records was successfully mounted on the publicly accessible QL Search System towards the end of the fiscal year. An information campaign advising potential clients of the file's availability for on-line searching is in progress.

Public access to the International Energy Agency's (IEA) Coal Database on the National Research Council's CAN/OLE on-line inquiry network was successfully launched in July 1981. TID is responsible for the database in Canada which now contains about 30 000 records contributed by member countries of the IEA Coal Research Group, Canada included. During 1981-82, TID provided 318 new Canadian items to the database. Efforts to bring the database to Canada and to make it directly accessible to Canadians, have been well rewarded; in less than one year 5904 searches were performed, 90% by non-CANMET personnel. This is a good indication of the degree of public need and interest in coal related information.

A database of current coal research projects in Canada as well as in other IEA member countries is planned for 1982-83.

Publications processing is one of the major activities of the division which involves technical editing, text preparation, proofreading, page layout, assembly for printing and binding, and primary distribution. In 1981-82 the division processed 474 reports and papers prepared by CANMET scientists. A total of 66 CANMET-sponsored contract reports were received for a grand total of 540 publications. Table 1 summarizes report categories and source.

Major publication projects completed during the year were the English editions of "A Canadian research heritage: 75 years of federal government research in minerals, metals and fuels" (353 p), "Rock mechanics principles", (revised)(460 p); and "Methods for the analysis of ores, rocks and minerals" (570 p). The French editions are in preparation and will be available during 1982-83.

Table 1 - CANMET publications by category and source, 1981-82

Category	MSL	ERL	MRL	PMRL	RPO	ERP	ADM	TID	TOTAL
CANMET Reports	5	3	2				2	2	14
Journal submissions	44	10	19	20					76
Oral presentations	10	11	14	8					43
Oral pres./conference papers	35	3	10	10					58
Divisional reports	61	18	78	36		4			197
Internal reports			7	12					19
Confidential reports	12	33	9	13					67
Contract reports					66				66
TOTAL	167	158	139	199	66	4	2	2	540
Declassified reports	329	6		4					339

INFORMATION DISSEMINATION

Dissemination of information comprises a variety of activities broadly divided into library and information retrieval services to CANMET staff in support of their research endeavours, and similar services to Canadians at large in consequence of CANMET's role as one of the principal nodes in the national science-technology information dissemination network.

In support of in-house research the CANMET library loaned 19 020 items to CANMET staff, in addition to circulating 47 373 issues of periodicals to individual CANMET scientists.

Loans to other libraries across the nation amounted to 5340 items, a substantial increase of 31% over the previous year. Library staff were able to satisfy nearly 80% of the requests. The remaining 20% which, for the most part, were marginal to CANMET's collection strength and interests, were routed to other government or private sector libraries and information centres. Conversely, CANMET scientists requested 2818 items not in the collections; these were obtained from other information resource centres.

The Technical Inquiries Response and Referral Service responded to 2486 major recorded inquiries, i.e., those requiring investigation, analysis and consultation with experts, or identification, retrieval and assembly of document packages, as in the case of general technical inquiries. This figure represents a minus 2% change from the previous year. Table 2 provides a breakdown of subjects and origin of inquiries.

Information officers also responded to 2187 minor undocumented inquiries. In addition, library reference staff responded to 992 general inquiries answerable from reference resources directly at hand.

Other products and services provided by TID to advance the diffusion of knowledge and information include:

(a) Current awareness lists are based on individually tailored interest profiles, and contain the most recent additions to about 10 different commercially produced databases. These have been produced for 88 subscribers within and outside CANMET. They are distributed monthly; in some instances more frequently.

(b) MINTEC FORTNIGHTLY is a classified compilation of the bi-weekly updates to TID's Mining Technology Database. Twenty-six issues of the bulletin were distributed to 80 subscribers, primarily researchers in government, industry and universities.

(c) Bibliography of Canadian Contributions to Rock Mechanics is an annual compilation by TID staff of papers on the subject by Canadians, culled from a wide range of sources. It includes papers published in technical journals, papers presented at various conferences or symposia, dissertations prepared for graduate degrees in the subject by Canadians, and other similar items. The 17th annual compilation was completed during the review period and published in the CIM Bulletin.

(d) Current Contents - East European Mining and Mineral Technology is a bi-monthly bulletin containing translated tables of contents from 30 to 40 East European periodicals dealing with mining and mineral technology. It is prepared by TID for distribution to EMR staff with responsibility for, or interest in, the development of these technologies in Soviet block countries. Five issues were prepared

Table 2 - Major inquiries processed by TID staff by subject and origin, 1981-82

	Within Canada						Outside Canada				Total	
	CANMET	Other EMR	Other Government	Educational Institution	Industry	Other	Government	Educational Institution	Industry	Other	No.	%
Mining	61	15	53	160	237	54	12	7	53	9	661	27
Min. Proc.	62	3	23	11	95	19	-	-	26	1	240	10
Metallurgy	92	4	29	19	129	33	1	1	15	4	327	13
Energy	57	30	61	26	60	69	3	8	23	5	342	14
East European	11	-	10	3	4	-	-	-	-	-	28	1
Gen'l Technical Inquiries	-	-	-	186	391	215	23	22	51	-	888	36
Totals: No.	283	52	176	405	916	390	39	38	168	19	2486	
%	12	2	7	16	38	16	1	1	7	0.5		100
Total within Canada											2222	91
Total outside Canada											225	9

during 1981-82; current distribution is to 26 officials throughout EMR.

(e) Open File Reports is a bi-monthly bulletin which contains information on recently released CANMET publications and research reports prepared by contractors of CANMET-sponsored projects. Six issues were completed in 1981-82 and distributed to more than 800 recipients throughout Canada.

(f) Catalogue of CANMET Publications is a consolidated annual listing of all publications processed and released during the year. The catalogue for 1981-82 as in past years, also provides source of availability for all publications and an abstract of the contents of all reports and papers in the CANMET Reports, External Journal Publications, and Oral Presentations series. The catalogue, a bilingual publication, was distributed to more than 1000 depository libraries, agencies and individuals interested in mineral and energy technology research.

APPENDIX A

CANMET PROFESSIONAL STAFF

DIRECTOR-GENERAL'S OFFICE

W.G. Jeffery; B.Sc., M.Sc. (Leeds); Ph.D. (McGill); Director-General
V.A. Haw; B.Sc., M.Sc. (Queen's); Deputy Director-General

RESEARCH PROGRAM OFFICE

V.A. Haw; B.Sc., M.Sc. (Queen's); Director, Minerals Research Program (MRP)
D.A. Reeve; B.Sc., Ph.D. (Birmingham); Director, Energy Research Program (ERP)
D.J. MacKinnon; Ph.D. (Ottawa); Assistant Director, Processing (MRP)
R.J.R. Welwood; B.Sc. (Queen's); Assistant Director, Mining and Supply (MRP)
W.N. Roberts; Ph.D. (Leeds); Assistant Director, Utilization (MRP)
G.S. Bartlett; B.Sc., B.A. (Memorial); Economist
R. Thomson, B.Sc., ARCST, Ph.D. (Glasgow); Assistant Director, Utilization and Materials (ERP)
H. Sawatzky; B.S.A., M.S.A., Ph.D. (Toronto); Assistant Director, Processing (ERP)

TECHNOLOGY INFORMATION DIVISION

J.E. Kanasy; B.Sc., B.A. (Windsor), M.A. (Michigan), Ph.D. (Pittsburgh); Chief of Division

LIBRARY

G. Peckham; B.A., B.L.S. (McGill); Chief Librarian
J. Ho; B.A., B.L.S. (Ottawa); Librarian
K. Nagy; B.Sc., B.L.S. (McGill); Librarian
I. Weniger; B.A., M.L.S. (Western); Librarian

TECHNICAL INQUIRIES

P.G. Sutterlin*; B.Sc. (McMaster), Ph.D. (Northwestern); Section Head
G.M. Blondeau, B.A. (Queen's), M.A. (Guelph); Mining Abstractor
C.F. Dixon; B.Eng., (N.S.T.C.), P.Eng.; Metall. Info. Off.
W. Kent; B.A. (Carleton); Documentation Coord.
R.T. Blake; A.C.S.M. (U.K.), P.Eng.; Mineral Tech. Info. Off.
D.B. Gladwin*; B.Sc., M.Sc. (Queen's); Min. Info. Off.
T.J. Patel; B.Sc. (Oregon State), M.Sc. (Washington State); Min. Proc. Abstractor
R.J.C. MacDonald*; B.Sc. (St. Francis Xavier); Min. Proc. Info. Off.
G.W. Taylor**; B.Sc. (Queen's); Energy Info. Off.

PUBLICATIONS

C. Mamen; B.Eng. (McGill), Eng.; Section Head, Editor
J. Collins-DeCotret; B.Com. (Ottawa); Ed. Asst. (French)

TECHNICAL SERVICES DIVISION

E.K. Swimmings; B.Sc. (Queen's), P.Eng.; Chief of Division
D.M. Norman; M.I.Mech. Eng. Borough Polytechnique (U.K.); Engineer

ENERGY RESEARCH LABORATORIES

B.I. Parsons; B.Sc., Ph.D. (McGill), D.Phil. (Oxford); Director

CANADIAN COMBUSTION RESEARCH LABORATORY

G.K. Lee; B.Sc., M.Sc. (Queen's), P.Eng., C.Eng.; Manager

EMERGING ENERGY TECHNOLOGY

F.D. Friedrich; B.Sc. (Saskatchewan), M.Sc. (Queen's), P.Eng.; Res. Sci.
E.J. Anthony; B.Sc., Ph.D. (Swansea), C.Chem.; Res. Sci.
D.L. Desai; B.E. (Sardar Patel), M.Eng. (Ottawa); Engineer
V.V. Razbin; Dipl. Eng. (Higher Mechand-Electrical Inst., Sofia, Bulgaria); Engineer

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*Transferred to Office of Technology Transfer 12/81
**Transferred to CREB 12/81

INDUSTRIAL HEAT PROCESSES

H. Whaley; B.Sc., Ph.D. (Sheffield), P.Eng., C.Eng.; Res. Sci.
G.N. Banks; B.A. (British Columbia); Res. Sci.
R.G. Fouhse; B.Sc. (Saskatchewan), P.Eng.; Engineer

ENERGY CONSERVATION

A.C.S. Hayden; B.Eng., M.Eng. (Carleton), P.Eng.; Res. Sci.
R.W. Braaten; B.Eng. (Carleton), P.Eng.; Engineer
C.E. Palmer; B.Eng. (New Zealand); Engineer
N.S.H. Stover; B.Sc. (Western Ontario); Engineer

ENGINEERING DESIGN AND PROJECT MONITORING

S.I. Steindl; Dipl. Eng. (Budapest), M.Sc. (Queen's), P.Eng.; Engineer

QUALITY ASSURANCE

R. Prokopuk; B.Sc. (Alberta); Phys. Sci.

COAL RESOURCE AND PROCESSING LABORATORY

T.D. Brown; B.Sc. (Durham), Ph.D. (Sheffield), C. Eng.; Manager

ANALYSES AND STANDARDIZATION

W.J. Montgomery*; B.S.A. (Toronto); Phys. Sci.
L.C.G. Janke; B.Sc. (Wilfrid Laurier), B.Ed. (Queen's); Phys. Sci.
J.Z. Skulski; Chem. Eng. (Wroclaw, Poland); Chemist

COAL TREATMENT

T.A. Lloyd; B.Sc. (Carleton); Phys. Sci.

COAL PETROGRAPHY

J.G. Jorgensen; B.Sc. (Carleton); Phys. Sci.

COAL AND PEAT RESOURCES

T.E. Tibbetts; B.Sc., B.Ed. (Dalhousie); Res. Sci.
D.K. Faurschou; B.A.Sc. (Toronto); Res. Sci.
J.R. Donaldson; B.A. (Acadia); Phys. Sci.
J. Margeson; B.Sc. (Carleton), M.Sc. (Ottawa); Res. Sci.

Evaluation Laboratory - Sydney, N.S.

G.W. Bonnell; B.Sc. (Dalhousie); Chemist

NEW PROCESS INVESTIGATIONS

C.J. Adams; B.Sc., M.Sc. (McGill), Ph.D. (McMaster), P.Eng.; Res. Sci.
M. Skubnik; B.Eng., M.Eng. (Bratislava, Czech.); Engineer
I. Lau; B.Sc. (Taiwan), M.A.Sc. (Ottawa); Engineer
B.J.P. Whalley**; B.Sc., Ph.D. (McGill); Res. Sci.

COAL AND COKE CONSTITUTION

B.N. Nandi; B.Sc., M.Sc. (Calcutta), Dr. Ing. (Karlsruhe); Res. Sci.
J.A. MacPhee; B.Sc. (St. Francis Xavier), Ph.D. (British Columbia); Res. Sci.
L. Ciavaglia; B.Eng. (Carleton); Phys. Sci.

CARBONIZATION RESEARCH

J.T. Price; B.Sc., M.Sc. (Calgary), Ph.D. (Western Ontario); Res. Sci.
J.F. Gransden; B.Sc. (London), A.R.S.M., Ph.D. (Western Ontario); Res. Sci.
V. Marwaha; B.Sc., (Punjab), M.A.Sc. (Windsor); Engineer

GASIFICATION RESEARCH

G.V. Sirianni; B.Sc. (Ottawa); Res. Sci.
D.P.C. Fung; B.Sc. (British Columbia), Ph.D. (Windsor); Res. Sci.
E. Furimsky; Dipl. Eng. (Prague), Ph.D. (Ottawa); Res Sci.

SYNTHETIC FUELS RESEARCH LABORATORY

J.M. Denis; B.A.Sc. (Ottawa), P.Eng.; Manager

PROCESS DEVELOPMENT

D.J. Patmore; B.Sc. (Bristol), Ph.D. (Alberta); Res. Sci.
D.D.S. Liu; B.Chem.Eng. (N. Taiwan), Ph.D. (Dalhousie); Res. Sci.
F.T.T. Ng; B.Sc. (Hong Kong), M.Sc. (British Columbia); Res. Sci.
T. de Bruijn; B.Sc., M.Sc., Ph.D. (Delft); Res. Sci.
R.B. Logie; B.Sc. (New Brunswick), P.Eng.; Engineer

CATALYSIS RESEARCH

M. Ternan; B.A.Sc. (British Columbia), Ph.D. (McGill), P.Eng.; Res. Sci.
J.F. Kriz; Dipl. Eng. (Prague), Ph.D. (Dalhousie), P.Eng.; Res. Sci.
J.R. Brown; B.Sc., Ph.D. (Western Ontario); Res. Sci.
M.F. Wilson; B.Sc., Ph.D. (St. Andrews); Res. Sci.
M.V.C. Sekhar; B.Sc. (Madras), M.Sc. (ITT-Madras), Ph.D. (Calgary); Res. Sci.
C.W. Fairbridge; B.Sc., M.Sc. (Lakehead), Ph.D. (St. Andrews); Res. Sci.
S. Ng; B.Eng. (Taiwan), Ph.D. (New Brunswick); Res. Sci.

COAL LIQUEFACTION

J.F. Kelly; B.Eng., Ph.D. (McGill), P.Eng.; Res. Sci.
S. Fouda; B.Eng., (Cairo), Ph.D. (Waterloo); Res. Sci.
R. Rahimi; B.Sc. (Iran), M.Sc. (Brock), Ph.D. (Alberta); Res. Sci.
P.L. Sears; M.A., Ph.D. (Cambridge); Res. Sci.

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*Retired 01/08/81
**Retired 30/12/80

RESEARCH ON BITUMINOUS SUBSTANCES

A.E. George; B.Sc., M.Sc., Ph.D. (Cairo); Res. Sci.
M.A. Poirier; B.Sc., M.Sc., Ph.D. (Montreal); Res. Sci.
S.M. Ahmed; B.Sc., M.Sc. (Osmania, India); Chemist
J.E. Beshai; B.Sc. (McMaster); Chemist

ANALYTICAL SECTION

D.M. Clugston; B.Sc., Ph.D. (McMaster); Chemist
L. Vancea; B.Sc., (Cluj), Ph.D. (Alberta); Chemist

EQUIPMENT DEVELOPMENT

L.P. Mysak; B.A.Sc. (Ottawa), P.Eng.; Engineer

WESTERN RESEARCH LABORATORY (EDMONTON)

W.R. Leeder; B.Sc., Ph.D. (British Columbia); Manager
J.L. Picard; B.Sc. (Alberta); Phys. Sci.

COAL BENEFICIATION

M.W. Mikhail; B.Sc. (Assiut), M.Sc. (Alberta), P.Eng.; Engineer
R.J. Mikula; B.Sc. (Saskatchewan), Ph.D. (British Columbia); Res. Sci.
A.I.A. Salama; B.Sc. (Alexandria), Ph.D. (Alberta); Res. Sci.
I.S. Parsons; B.Sc. (Western Ontario); Phys. Sci.

CARBONIZATION

A.B. Fung; B.Sc. (Waterloo), P.Eng.; Engineer
R. Zrobok; B.Sc. (Alberta); Phys. Sci.

COLLOID AND SURFACE SCIENCE APPLICATIONS

H.A. Hamza; B.Sc. (Cairo), Ph.D. (Newcastle-on-Tyne); Res. Sci.
N.E. Andersen; B.Sc. (Alberta); Phys. Sci.
K.A. Hashmi; B.Sc. (Alberta); Engineer
W.I. Friesen; B.Sc. (Brock), Ph.D. (British Columbia); Res. Sci.
K.H. Michaelian; B.Sc. (California State), Ph.D. (Simon Fraser); Res. Sci.

MINING RESEARCH LABORATORY

T.S. Cochrane; B.A.Sc., M.Sc. (Washington); P.Eng.; Director

ROCK MECHANICS LABORATORY

G.E. Larocque; B.Sc. (Carleton); Manager
A. Boyer; B.Sc. (Montreal); Phys. Sci.
R. Boyle; B.Sc. (Ottawa); Comp. Sci.
A. Fustos; B.S.F./F.E., B.Sc. (UBC); P.Eng.; Engineer
L. Geller; Dipl. Mech. Eng. (Budapest); B.Sc. (Eng.) (London), M.A.Sc. (Toronto); Phys. Sci.
M. Gyenge; Dipl. Eng. (Budapest), P.Eng.; Res. Sci.
R.L. Sabourin; B.Sc., M.Eng. (Ecole Polytechnique) P.Eng.; Engineer
N.A. Toews; B.Sc. (Queen's); Res. Sci.
Y.S. Yu; B.Sc., M.Eng. (McGill); Res. Sci.
D.F. Walsh; B.Sc. (Memorial); Phys. Sci.
A.S. Wong; B.Sc. (National Taiwan University), M.Sc. (Ottawa); Phys. Sci.
A.B. Annor; B.A.Sc. (Ottawa); P.Eng.; Phys. Sci.
R. Jackson; B.A.Sc. (Waterloo); Phys. Sci.
J. Pathak; B.E., M.Eng. (Sager, India); Ph.D. (Freiberg, Germany); Engineer

ELLIOT LAKE LABORATORY

R.O. Tervo; B.A.Sc. (Toronto), Ph.D. (Bradford), P.Eng.; Manager
J. Bigu; M.Sc. (Barcelona), Ph.D.; Res.Sci.
V. deKorompay*; Dipl. Min. Eng. (Hungary); Phys. Sci.
M. Gangal; B.Sc. (Agra, India), M.Sc. (Rokee, India & McGill), Ph.D. (Calgary); Res. Sci.
D.G.F. Hedley; B.Sc., Ph.D. (Newcastle), P.Eng. Res. Sci.
G. Knight; B.Sc. (Birbeck, London); Res. Sci.
D.R. Murray; B.A.Sc. (McDonald College); Phys. Sci.
M. Savich; Dipl. Min. Eng. (Ljobljan, Yugoslavia), B.Eng., M.Eng. (McGill); Res. Sci.
N.K. Davé; B.Sc., M.Sc., (Rajastman, India), Ph.D. (Queen's); PDF
M. Grenier; B.Sc. (Laurentian); Phys. Sci.
T.P. Lim; B.Sc. (Ottawa); Phys. Sci.
B. Arjang; B.Sc., M.Sc., Ph.D. (Germany); Res. Sci.
P. MacDonald; B.Sc., M.Sc., Ph.D. (England); Res. Sci.

CANADIAN EXPLOSIVES RESEARCH LABORATORY

J.A. Darling**; B.A. (Queen's); Manager
R.R. Vandebeek; B.Sc., M.Sc. (Carleton); A/Manager
K.C. Cheng; B.Sc., M.Eng. (Tainan Chen-Kung, Taiwan); Engineer
E. Contestabile; B.Sc. (Carleton); Phys. Sci.
K.K. Feng; B.Sc., M.Sc., Ph.D. (Iowa); Res. Sci.
C.A. Vary; B.Sc. (Ottawa); Tech. Off.
P. Lee; B.Sc. (Hong Kong Baptist); Chemist

WESTERN OFFICE, CALGARY

G. Zahary; B.Sc., M.Eng. (McGill); P.Eng.; Manager
R.N. Chakravorty; B.Che., (Jadavpur, India), Ph.D. (Nottingham); Res. Sci.
B. Das; B.ME (School of Mines, India), Ph.D. (Tech. Univ. of Mines, Czechoslovakia); Engineer
M.Y. Fisekci; Dipl. Eng., M.Eng., Ph.D. (Sheffield); Res. Sci.
A.S. Romaniuk; B.Sc. (Queen's); P.Eng.; Phys. Sci.
V. Srajer; M.A.Sc. (Mining) (Univ. of Applied Science, Czechoslovakia); Engineer

CANADIAN EXPLOSIVE ATMOSPHERES LABORATORY

J.A. Bossert; B.Sc., (Queen's); Manager
E.D. Dainty; B.Sc., M.Sc., (Toronto) P.Eng.; Res. Sci.
G. Lobay; B.Sc., (Manitoba); Engineer
P. Mogan; B.A.Sc. (Toronto), P.Eng.; Res. Sci.

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*Retired 21/09/81
**Retired 27/11/81

N. Sarin; Dipl. (Mech. & Auto Eng.) (Oxford College of Technology), B.A.Sc. Mech.Eng. (Waterloo); Engineer
S. Silver; B.Sc., (Manitoba); Res. Sci.
J. Szymanski; B.Sc., M.Sc. (M.Eng.), M.Sc. (Mech. Eng.), Ph.D. (Mech. Eng.) (Wroclaw, Poland); PDF

MINERAL SCIENCES LABORATORIES

W.A. Gow; B.A.Sc. (Toronto); Director
E.G. Joe; B.Sc. (Queen's); Phys. Sci.

CHEMICAL LABORATORY

R.G. Sabourin; B.Sc. (Ottawa); Manager
C.H. McMaster*; B.Sc., M.Sc. (Queen's); Assistant Manager

METALS AND ALLOYS

D.J. Barkley; B.Sc. (Carleton); Chemist
E.H. MacEachern; B.Sc. (Mount Allison); Chemist
J.W. Wittwer; B.Sc. (Carleton); Chemist

ORES AND FIRE ASSAY

J.C. Hole; B.A. (Toronto); Chemist
R.R. Craig; B.Sc. (Glasgow); Chemist

RADIATION AND MINERAL PHYSICS

M.G. Townsend; B.Sc., Ph.D. (Southampton); Res. Sci.
A. Leclerc; B.Sc., Ph.D. (Ottawa); Res. Sci.

SOLUTION CHEMISTRY

R.J. Guest; B.Sc. (Acadia); Res. Sci.
G.A. Hunt; B.Sc. (Carleton); Chemist
J.E. Atkinson; B.A. (Queen's); Chemist

SPECTROCHEMISTRY

G.L. Mason**; A.Metallurgy (Sheffield); Chemist
J.L. Dalton; B.S., M.Eng. (Carleton); Chemist
C.W. Smith; M.Sc., Ph.D. (Queen's); Chemist
T.R. Churchill; B.Sc. (Western Ontario); Chemist
R.E. Horton; B.Sc. (Carleton); Chemist

SPECIAL ANALYSES

A. Hitchen; B.Sc. (McMaster); Chemist
B. Nebesar; M.Sc. (McGill); Res. Sci.
M.E. Leaver; B.Sc. (Queen's); Chemist

SPECIAL PROJECTS
(Research, standard methods and reference materials)

E.M. Donaldson; B.Sc. (Manitoba); Res. Sci.
E. Mark; B.A. (Toronto); Chemist
H.F. Steger; B.Sc., Ph.D. (McMaster); Res. Sci.

EXTRACTIVE METALLURGY LABORATORY

M.C. Campbell; B.Sc. (St. Francis Xavier), B.Eng. (N.S.T.C.), D.I.C., M.Sc. (London), P.Eng.; Manager

ENGINEERING AND EVALUATION*

W.J. Craigen; B.Sc. (Queen's); Phys. Sci.
F.J. Kelly; B.Eng. (N.S.T.C.); Res. Sci.
J. Palmer; B.Sc. (Aberdeen), P.Eng.; Engineer
W.S. Wong; B.Eng. (McMaster), P.Eng.; Engineer
R. Philar; M.S. (Connecticut), M.B.A., P.Eng.; Engineer

METALLURGICAL CHEMISTRY

J.E. Dutrizac; B.A.Sc., M.A.Sc., Ph.D. (Toronto); Res. Sci.
D.J. MacKinnon; B.Sc., M.A., Ph.D. (Ottawa); Res. Sci.
P. Pint; B.A.Sc., M.A.Sc., Ph.D. (Toronto); Res. Sci.
K. Bartels; B.Sc. (Carleton); Chemist
E. Rolia; B.A. (UBC); Chemist
O. Dinardo; B.Sc. (Carleton); Phys. Sci.

PHYSICAL CHEMISTRY

A.H. Webster; B.A., M.A., Ph.D. (UBC); Res. Sci.
S.M. Ahmed; B.Sc., Ph.D. (Saskatchewan); Res. Sci.
R.F. Pilgrim; B.Sc. (Queen's); Res. Sci.
R. Sutarno; B.E., M.E., Ph.D. (N.S.T.C.), P.Eng.; Res. Sci.
S.A. Mikhail; B.Sc., M.Sc., Ph.D. (Cairo); Dr. Eng. (Norway); Res. Sci.
L.G. Ripley; B.Sc., M.A. (Queen's); Res. Sci.
V.H.E. Rolko; B.Sc. (Manitoba); Chemist

PROCESS METALLURGY

G.M. Ritcey; B.Sc. (Dalhousie); Res. Sci.
B.H. Lucas; B.Sc. (Queen's), P.Eng.; Res. Sci.
A.J. Gilmore; B.Sc. (Manitoba); Res. Sci.
K.E. Haque; M.Sc., Ph.D. (Ottawa); Res. Sci.
V.N. Saleh; B.A.Sc. (Ottawa); Engineer
C. Hamer; B.E. (N.S.T.C.), M.Sc. (Queen's) P.Eng.; Res. Sci.
H.W. Parsons; B.Sc. (Alberta); Res. Sci.
V.M. McNamara; B.Sc., B.Eng., M.A.Sc. (Toronto), P.Eng.; Res. Sci.
J.M. Skeaff; B.A.Sc., M.A.Sc., Ph.D. (Toronto); Res. Sci.
A. Jongejan; Geol. Can. Drs. (Amsterdam), Ph.D.; Res. Sci.
M. Silver; B.Sc., M.Sc. (Manitoba); Ph.D. (Syracuse); Res. Sci.

MINERAL PROCESSING LABORATORY

G.W. Riley; A.C.S.M. (Camborne School of Mines), P.Eng., Manager

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*Retired 30/12/80
**Retired 7/10/81

*Transferred to Office of Technology Transfer 12/81

CERAMICS

K.E. Bell; B.E. (Saskatchewan), P.Eng.; Res. Sci.
V.V. Mirkovich; Ph.D. (Toronto); Res. Sci.
D.H.H. Quon; B.Sc. (National Sun Yat Sen U.), M.Sc. (Ohio State), Ph.D. (Michigan); Res. Sci.
T.A. Wheat; Ph.D. (Leeds); Res. Sci.
A.K. Kuriakose; Ph.D., M.A., B.Sc. (Madras, India); Res. Sci.

CONSTRUCTION MATERIALS

V.M. Malhotra; B.Sc., B.E. (W. Australia); Res. Sci.
H.S. Wilson; B.E. (Saskatchewan); Res. Sci.
G.G. Carette; B.Sc. (Laval); Engineer

CRYSTAL STRUCTURE

J.T. Szymanski; B.Sc., Ph.D. (London); Res. Sci.
J.F. Rowland; B.Sc., M.Sc. (Queen's); Res. Sci.

MINERAL PROCESSING

L.L. Sirois; B.A., B.Eng., M.Eng. (McGill), P.Eng.; Res. Sci.
G.I. Mathieu; B.A., B.Sc. (Laval); Res. Sci.
D. Raicevic*; B.Sc. (Belgrade); Res. Sci.
A.I. Stemerowicz; B.Sc. (Queen's), P.Eng.; Res. Sci.
D. Laguitton; Chem. Eng. (Rennes), D.Sc. (Laval); Res. Sci.
K.S. Moon; B.Sc., M.Eng. (Seoul National U.); M.A.Sc., M.Eng. (British Columbia), Ph.D. (California); Res. Sci.
J.H.C. Leung; B.Sc. (Taiwan), M.Sc. (Waterloo); Phys. Sci.
J.M.D. Wilson; B.Sc., M.A.Sc. (Queen's); Phys. Sci.
W.H. Cameron; B.Sc. (Queen's); Phys. Sci.

MINERALOGY

R.M. Buchanan; B.A., M.A. (Toronto); Phys. Sci.
L.J. Cabri; B.Sc., M.Sc., Ph.D. (McGill); Res. Sci.
J.L. Jambor; B.A., M.Sc., Ph.D. (Carleton); Res. Sci.
W. Petruk; B.Eng., M.Sc., Ph.D. (McGill); Res. Sci.
T.T. Chen; B.Sc. M.Sc., Ph.D. (Cornell); Res. Sci.
J.A. Soles; B.A.Sc., M.A.Sc. (British Columbia), Ph.D. (McGill), P.Eng.; Res. Sci.
M.R. Hughson; B.A. (Western Ontario); Phys. Sci.

NON-METALLIC AND WASTE MINERALS

R.K. Collings; B.Eng. (N.S.T.C.), P.Eng.; Res. Sci.
S.S.B. Wang; B.Sc. (Hong Kong Baptist); M.Sc. (California), Ph.D. (Toronto); Phys. Sci.
P.R.A. Andrews; B.Sc., (Eng.) (London), M.Eng.Sc. (Melbourne); Res. Sci.

VISITING RESEARCH FELLOWS

A. Ahmad; B.Sc., M.Sc., Ph.D. (New Brunswick)
R. McMillan; Ph.D. (British Columbia)
R.M. Morrison; Ph.D. (British Columbia)

PHYSICAL METALLURGY RESEARCH LABORATORIES

W.H. Erickson; B.Sc., M.Sc. (Mich. Tech); Ph.D. (Durham), P.Eng.; Director

METAL PROCESSING LABORATORY

J.T. Jubb; B.A.Sc., M.A.Sc., Ph.D. (Toronto); Manager

FOUNDRY

R.K. Buhr; B.Eng. (McGill); Head
K.G. Davis; B.Sc. (Birmingham), M.A.Sc., Ph.D. (British Columbia); Res. Sci.
J.L. Dion; B.A.Sc. (Montreal), P.Eng.; Phys. Sci.
B. Lagowski; B.Sc., M.Sc. (Polish Univ. London); Res. Sci.
E.I. Szabo; M.Sc., Ph.D. (Nottingham); Res. Sci.
R.D. Warda; B.A.Sc. (British Columbia), Ph.D. (Cambridge); Res. Sci.
L. Whiting; B.Sc., M.Sc., Ph.D. (McGill), MBA (Ottawa); Res. Sci.

METAL FORMING

A.F. Crawley; B.Sc., Ph.D. (Glasgow), P.Eng; Head
D.L. Baragar; B.Sc., M.Sc., Ph.D. (Queen's); Res. Sci.
W.A. Pollard; B.Sc., A.R.S.M. (London), P.Eng.; Res. Sci.
G.E. Ruddle; B.A.Sc., M.Sc. (Waterloo), D.Sc. (Virginia), P.Eng.; Res. Sci.

NONDESTRUCTIVE TESTING

V.L. Caron; B.A.Sc. (Laval), M.Eng. (Paris) P.Eng.; Head

WELDING

J.T. McGrath; B.A.Sc., M.A.Sc., Ph.D. (Toronto), P.Eng.; Head
R. Chandel; B.E. (Nagpur), Ph.D. (Birmingham); Res. Sci.
Z. Paley; B.Sc., M.Sc. (Halifax), Ph.D. (McGill); Res. Sci.
R.D. McDonald; B.Sc. (Queen's), P.Eng.; Res. Sci.

METAL DEVELOPMENT LABORATORY

D.W.G. White; S.M., Sc.D. (M.I.T.), P.Eng.; Manager

CORROSION SCIENCE

J.B. Gilmour; B.Sc. (Queen's), Ph.D. (McMaster), P.Eng.; Head
G.J. Biefer; B.Sc., Ph.D. (McGill); Res. Sci.
R.J. Brigham; B.Sc., M.Sc., Ph.D. (McMaster); Res. Sci.

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*Retired 25/05/81

D.C. Briggs; B.Eng., M.Eng. (McGill), Ph.D. (Queen's); Res. Sci.
G.R. Hoey; B.Sc., M.Sc., Ph.D. (Toronto); Res. Sci.
A.W. Lui; B.Sc., M.A.Sc., Ph.D. (Windsor); Res. Sci.
W.R. Revie; B.Eng. (McGill), M.Eng. (R.P.I.), Ph.D. (M.I.T.); Res. Sci.
J.C. Saiddington; Chem. Eng., M.A.Sc. (Toronto); Res. Sci.
V.S. Sastri; B.Sc., M.A., Ph.D. (New York); Res. Sci.

ENGINEERING AND METAL PHYSICS

W.R. Tyson; B.A.Sc. (Toronto), Ph.D. (Cambridge); Head
R. Bell; B.Sc., Ph.D. (Queen's, Belfast), P.Eng.; Res. Sci.
G. Carpenter; B.Sc., Ph.D. (Wales); Res. Sci.
O. Vosikovsky; B.A.Sc., Ph.D. (Prague); Res. Sci.
K.C. Wang; B.A.Sc., Ph.D. (Rensselaer); Res. Sci
P.J. Todkill*; B.A.Sc. (Toronto); Engineer
J. Harbec; B.Eng. (McGill), P.Eng.; Phys. Sci.
E.J. Cousineau; B.Sc. (Carleton); Phys. Sci.
K.S. Milliken; B.Sc. (Queen's); Res. Sci.
C.M. Mitchell; B.A.Sc., M.A.Sc., Ph.D. (Toronto); Res. Sci.
J. Ng-Yelim; B.A. (Carleton), B.Sc. (Ottawa); Phys. Sci.
R.H. Packwood; B.Sc., Ph.D. (Birmingham); Res. Sci.
G. Roj; M.Sc. (Silesian), Ph.D. (P.A.M.); Res. Sci.

METALLURGY

J.D. Boyd; B.A.Sc. (Toronto), Ph.D. (Cambridge); Head
L. Collins; B.Sc., M.Sc. (Queen's), Ph.D. (M.I.T.); Res. Sci.
D.M. Fegredo; B.Sc., M.Sc., Dipl., I.I.Sc., Ph.D. (Sheffield), A.I.M.; Res. Sci.
M.J. Godden; B.Met., Ph.D. (Sheffield); Res. Sci.
R.F. Knight; B.Sc., M.Sc. (Queen's); Res. Sci.
A. Couture; B.A., B.A.Sc. (Laval), P.Eng.; Res. Sci.
M. Sahoo; B.Sc., B.E. (I.I.Sc., Bangalore) Ph.D. (British Columbia), P.Eng.; Res. Sci.
M.J. Lavigne; B.A., B.A.Sc., Ph.D. (Laval); Res. Sci.
T. Malis; B.Sc., M.E., M.Sc., Ph.D. (Manitoba); Res. Sci.
D.E. Parsons; B.A.Sc. (Toronto); Res. Sci.
M.T. Shehata; B.Eng. (Cairo), Ph.D. (McMaster); Res. Sci.

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*Retired 30/12/81

APPENDIX B

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BRITISH FLAME RESEARCH COMMITTEE (member) .... G.K. Lee (ERL)

CANADA/JAPAN COAL LIQUEFACTION COORDINATING COMMITTEE

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FUEL (London) (Eastern regional editor)

International Editorial Board (Canadian editor) .... A.E. George (ERL)

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Petrography of Organic Sediments (member) .... B.N. Nandi (ERL)
Subcommittee on Industrial Applications of Coal Petrology (member) .... B.N. Nandi (ERL)

INTERNATIONAL COMMITTEE FOR COAL RESEARCH (member) .... D.A. Reeve (RPO)

INTERNATIONAL COMMITTEE FOR SOLVENT EXTRACTION TECHNOLOGY (member) G.M. Ritcey (MSL)

INTERNATIONAL CONFERENCE ON APPLIED MINERALOGY
IN THE MINERAL INDUSTRY (Canadian Representative, 1981) .... W. Petruk (MSL)
Organizing Committee, 1984 (co-chairman) .... W. Petruk (MSL)

INTERNATIONAL CONFERENCE ON PIPELINE INSPECTION
Steering Committee (chairman) .... R.W. Revie (PMRL)

INTERNATIONAL CONFERENCE ON THERMAL CONDUCTIVITY CONFERENCE (director) .... V.V. Mirkovich (MSL)

INTERNATIONAL CONGRESS ON CRYSTALLOGRAPHY (12th)
Organizing Committee and Program Committee (member) .... J.T. Szymanski (MSL)

INTERNATIONAL CONGRESS ON METALLIC CORROSION (9th)

Technical Program Committee (member) .... R.W. Revie (PMRL)

INTERNATIONAL ELECTROTECHNICAL COMMISSION

Committee 31, Electrical Apparatus for Explosive Atmospheres (chairman) .... J.A. Bossert (MRL)
Subcommittee 31A, Flameproof Enclosures (chairman) .... J.A. Bossert (MRL)

AFFILIATION KEY:

DGO	Director-General's Office
ERL	Energy Research Laboratories
MRL	Mining Research Laboratories
MSL	Mineral Sciences Laboratories
PMRL	Physical Metallurgy Research Laboratories
RPO	Research Program Office
TID	Technology Information Division

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Coal Services	
Mining Technology Clearing House	
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Technical Information Service	
Executive Committee (member)	D.A. Reeve (RPO)
Technical Committee (member)	J.E. Kanasy (TID)
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Atmospheric Fluidized Bed Combustion Agreement	F.D. Friedrich (ERL)
Low NO_x Coal Combustion of Pulverized Coal Agreement	G.K. Lee (ERL)
Organizing Committee - International Conference on Coal Science	J.T. Price (ERL)
Fossil Fuels Working Party (chairman)	D.A. Reeve (RPO)
Task VI (Photocatalytic Water Electrolysis) of the Program of Research and Development on Production of Hydrogen from Water (Canadian Technical Contact Person)	S.M. Ahmed (MSL)
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Flame Chemistry Panel (member)	E.J. Anthony (ERL)
Joint Committee (member)	G.K. Lee (ERL)
Pulverized-Coal Panel (member)	G.K. Lee (ERL)
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Canadian Council (vice-chairman)	J.T. McGrath (PMRL)
Commission X, Residual Stress, Stress Relieving Brittle Fracture (chairman)	J.T. McGrath (PMRL)
INTERNATIONAL JOURNAL OF HYDROMETALLURGY (editor)	G.M. Ritcey (MSL)
Editorial Board (members)	D.J. MacKinnon (MSL) G.M. Ritcey (MSL)
INTERNATIONAL JOURNAL OF PRESSURE VESSEL AND PIPING	
Editorial Board (member)	J.T. McGrath (PMRL)
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Organizing committee (member)	M.C. Campbell (MSL)
INTERNATIONAL MINE VENTILATION CONGRESS (member)	G. Knight (MRL)
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Committee on Sulphosalts (member)	T.T. Chen (MSL)
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REMCO, Reference Materials (chairman)	R.G. Sabourin (MSL)
TC17/SC1, Analysis of Steel and Cast Iron (member)	R.G. Sabourin (MSL)
SC4, Heat Treated Alloy and Free-Cutting Steels (members)	R.K. Buhr (PMRL) D.E. Parsons (PMRL)
SC6, Methods of Mechanical Testing (chairman)	D.E. Parsons (PMRL)
SC7, Test Methods other than Mechanical (member)	D.E. Parsons (PMRL)
SC11, Steel Castings (secretary)	D.E. Parsons (PMRL)
(member)	V. Caron (PMRL)
SC15, Rail Steels (member)	D.E. Parsons (PMRL)
TC24, Sieves, Sieving and other Sizing Methods (members)	G.W. Riley (MSL) L.L. Sirois (MSL)
TC25, Cast Iron (member)	R.K. Buhr (PMRL)
TC26, SC1, Copper and Copper Alloys (member)	R.G. Sabourin (MSL)

TC27, Solid Mineral Fuels (chairman)	W.J. Montgomery (ERL)
(member)	L. Janke (ERL)
SC2, Brown Coals & Lignites (member)	W.J. Montgomery (ERL)
(member/secretary)	L. Janke (ERL)
SC3, Coke (members)	W.R. Leeder (ERL)
	J.F. Gransden (ERL)
WG6, Evaluation of Flocculants for use in Coal Preparation (convener)	H.A. Hamza (ERL)
WG9, Grindability (member)	W.J. Montgomery (ERL)
WG12, Plasticity (member)	T.A. Lloyd (ERL)
WG13, Ash Analysis (secretary)	W.J. Montgomery (ERL)
(member)	L. Janke (ERL)
WG14, Trace Analysis (member/secretary)	L. Janke (ERL)
TC33, Refractories (member)	K.E. Bell (MSL)
TC56, Mica (chairman)	G.W. Riley (MSL)
TC69, Application of Statistics (member)	R. Sutarno (MSL)
SC6, Precision (Canadian representative)	R. Sutarno (MSL)
TC71/SC1, SC3, Concrete (chairman)	V.M. Malhotra (MSL)
TC77, Asbestos (member)	G.W. Riley (MSL)
TC79, Light Metals and their Alloys (member)	P.J. Todkill (PMRL)
TC82, Mining (chairman)	R. Welwood (RPO)
TC91, Evaluation of Surface Active Agents (member)	H.A. Hamza (ERL)
TC102, Iron Ores (chairman)	G.W. Riley (MSL)
(member)	R. Sutarno (MSL)
SC1, Sampling (chairman)	R. Sutarno (MSL)
(member)	G.W. Riley (MSL)
SC2, Chemical Analysis (chairman)	G.W. Riley (MSL)
(member)	J.C. Hole (MSL)
Reference Materials (Canadian representative)	R. Sutarno (MSL)
WG12, Statistical Methods (convener)	R. Sutarno (MSL)
SC3, Physical Testing of Iron Ores (chairman)	J.T. Price (ERL)
(member)	G.W. Riley (MSL)
SC4, Size Determination, Iron Ores (chairman)	G.W. Riley (MSL)
(member)	G.W. Riley (MSL)
TC107/SC6, Metallic and other Inorganic Coatings (member)	K.E. Bell (MSL)
TC109, Domestic Oil Burners (member)	A.C.S. Hayden (ERL)
TC111/SC1, Chain (member)	R.K. Buhr (PMRL)
TC119, Testing of Powder Metallurgical Materials and Products (member)	H.M. Skelly (PMRL)
TC135/SC7, NDT Personnel Qualification, International Secretariat (secretary)	V. Caron (PMRL)
TC146 Air Quality (member)	G.W. Riley (MSL)
SC1, Stationary Source Emissions (member)	H. Whaley (ERL)
SC2, Workplace (member)	G.W. Riley (MSL)
SC2/WG5, Inorganic Fibres (chairman)	G.W. Riley (MSL)
SC2/WG1, 5, (member)	G. Knight (MRL)
TC155, Nickel and Nickel Alloys (members)	M.J. Lavigne (PMRL)
	R. Sutarno (MSL)
(statistician)	R. Sutarno (MSL)
TC156/WG1 Corrosion of Metals and Alloys/Terminology (member).	G.J. Beifer (PMRL)
TC163/SC3, SC4, Insulation (member)	S.S. Wang (MSL)
TC164, Mechanical Testing of Metals (chairman)	P.J. Todkill (PMRL)
(members)	A.F. Crawley(PMRL)
	O. Vosikovsky (PMRL)
TC166, Ceramic Ware in Contact with Foods (member)	K.E. Bell (MSL)
TC175, Fluorspar Ore (member)	R.M. Buchanan (MSL)

INTERNATIONAL PEAT SOCIETY (vice-president)	T.E. Tibbetts (ERL)
Canadian National Committee (secretary-treasurer)	T.E. Tibbetts (ERL)

INTERNATIONAL SOCIETY FOR ROCK MECHANICS

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INTERNATIONAL SOLVENT EXTRACTION TECHNOLOGY COMMITTEE (member)	G.M. Ritcey (MSL)

INTERNATIONAL STRATA CONTROL CONFERENCE (7th) (1982)

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INTERNATIONAL THERMAL CONDUCTIVITY CONFERENCE (director) .... V.V. Mirkovich (MSL)

INTERNATIONAL TUNNELLING ASSOCIATION

Tunnelling Association of Canada (member) .... L. Geller (MRL)

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.... C.M. Mitchell (PMRL)
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Non-Commercial Exhibit Committee (chairman) .... C.M. Mitchell (PMRL)
(member) .... K.S. Milliken (PMRL)
Crystallographic Studies at Controlled Pressure (co-chairman). C.M. Mitchell (PMRL)
Renaissance of Powder Diffraction (co-chairman) .... C.M. Mitchell (PMRL)

INTERNATIONAL UNION OF PURE AND APPLIED CHEMISTRY 1981 CONGRESS
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(member) .... V.M. Malhotra (MSL)
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International Group of Experts on Unstable Substances
(member) .... J.A. Darling (MRL)
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Technical Activities (member)	V.M. Malhotra (MSL)
Committee 548, Polymers in Construction (member)	V.M. Malhotra (MSL)
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Editorial Board, International Cast Metals Journal (member)	R.K. Buhr (PMRL)

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Editorial Board (member)	D.J. MacKinnon (MSL)
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Task Force on Energy Conversion Research (member)	G.K. Lee (ERL)
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(asst. secretary-treasurer)	M. Sahoo (PMRL)
(secretary-treasurer)	J.T. McGrath (PMRL)

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C-9, Concrete (member)	V.M. Malhotra (MSL)
C-9-09-05, Nondestructive Testing of Concrete (chairman)	V.M. Malhotra (MSL)
D-5, Coal and Coke (chairman)	W.J. Montgomery (ERL)
D-5-02, Nomenclature and Definitions (member)	W.J. Montgomery (ERL)
D-5-07, Physical Properties of Coal (member)	T.A. Lloyd (ERL)
D-5-15, Plasticity and Swelling (member)	T.A. Lloyd (ERL)
D-5-21, Methods of Analysis (members)	W.J. Montgomery (ERL)
	L. Janke (ERL)
D-5-22, Physical Testing of Coke (member)	T.A. Lloyd (ERL)
D-5-27, American Group ISO/TC-27 (member)	W.J. Montgomery (ERL)
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Task Group T-1F-9, Metallics Materials Testing Techniques for Sulphide Corrosion Cracking (member)	G.J. Biefer (PMRL)
Task Group T-1F-17, Sulphide Stress Cracking Data by NACE Tensile Test Procedure (member)	G.J. Biefer (PMRL)
Task Group T-1F-20, Stepwise Cracking of Pipeline Steels (member)	G.J. Biefer (PMRL)
Unit Committee T-1F, Metallurgy of Oil Field Equipment (member)	G.J. Biefer (PMRL)
Unit Committee T-3N, Corrosion by De-icing Salts (member)	R.D. McDonald (PMRL)

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U.S./CANADA MEMORANDUM OF INTENT FOR CONTROL OF LONG RANGE TRANSPORT OF AIR POLLUTANTS

Work Group 3B (member)	W.J. Craigen (MSL)

U.S./CANADA MEMORANDUM OF UNDERSTANDING FOR COOPERATION ON RESEARCH AND DEVELOPMENT IN TAR SANDS (OIL SANDS) AND HEAVY OIL

Executive Committee (Canadian chairman)	B.I. Parsons (ERL)

U.S./CANADA RESEARCH COMMITTEE ON THE LONG TRANSPORT OF AIR POLLUTANTS (member)	H. Whaley (ERL)
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